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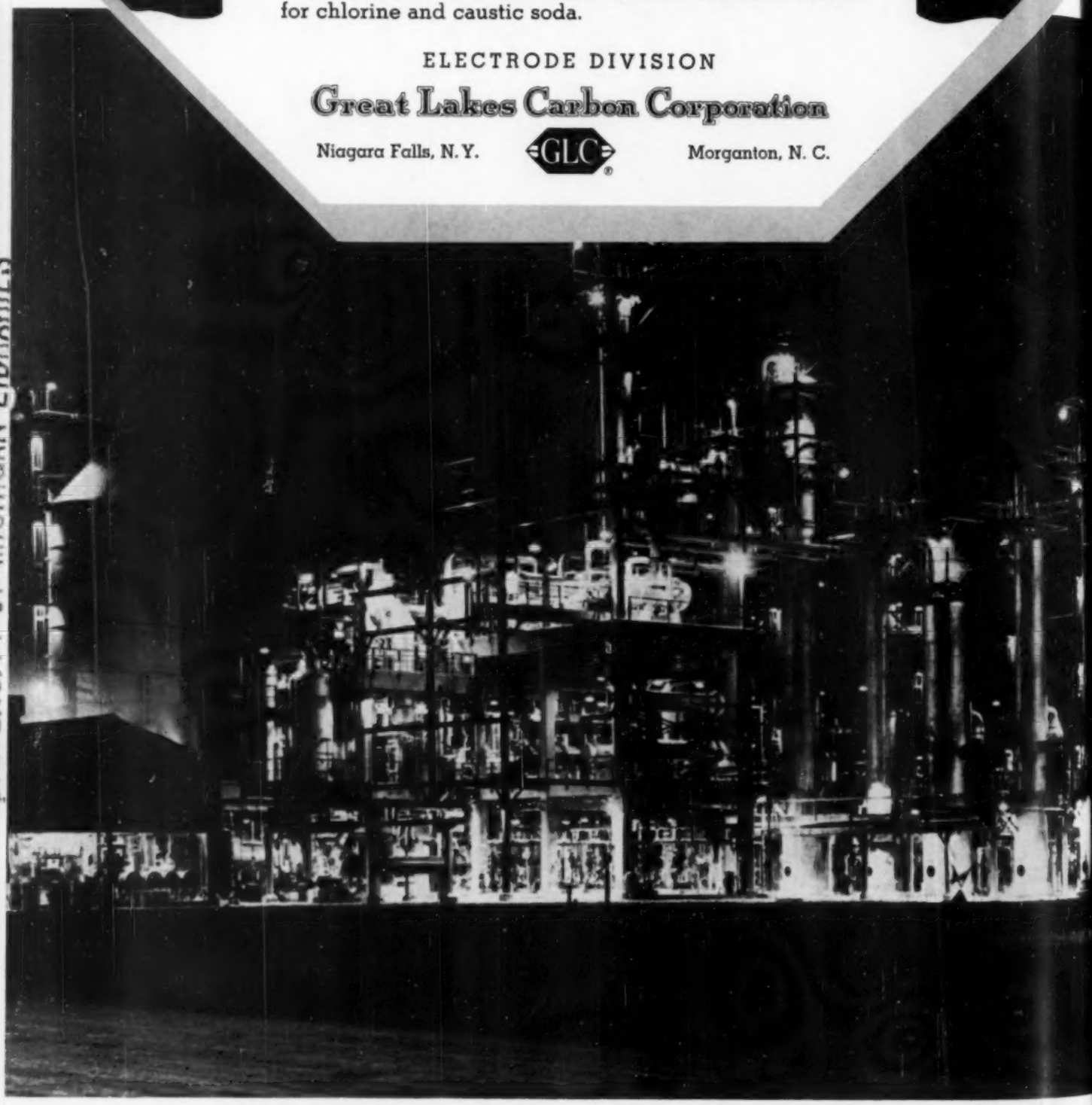

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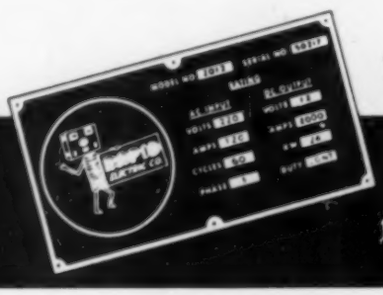

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The Anodizing of Zirconium and Other Transition Metals in Nitric Acid[1]

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Metallurgy Division, Argonne National Laboratory, Lemont, Illinois

ABSTRACT

Zirconium was anodized in solutions of nitric acid and compared with certain other transition metals. At 1 ma/cm² and concentrations of nitric acid exceeding 14 weight per cent, zirconium was found to develop a low-resistance oxide layer. Titanium, hafnium, columbium, tantalum, and tungsten showed a high resistance at this current even in 70 weight per cent acid. Hafnium, however, produced a low-resistance film at lower current densities. Zirconium, in nitric acid above 14 weight per cent, showed periodic changes of resistance with time. The transition was dependent upon grain orientation and metal texture.

As the concentration of nitric acid was increased, the anodic layer changed in appearance from white to gray to black. These products were all monoclinic ZrO_2. The white oxide was friable, and developed from a thin barrier layer. The black oxide was hard and coherent, and comprised the entire layer. It is suggested that these layers differed in the number of anion defects, and varied from stoichiometric (white) to anion-defect semiconducting (black).

Introduction

The anodizing of zirconium in nitric acid was found to have unusual characteristics in comparison with other transition metals which form anodic films. The metals included in this study were titanium, zirconium, hafnium, columbium, tantalum, and tungsten. At room temperature, these metals are not significantly attacked by nitric acid at any concentration (1, 2). When made anodic in most electrolytes, the metals acquire an oxide film which usually attains a limiting thickness (3). Zirconium was found to be an exception, however, and some details of its behavior are given here.

The anodizing and electrolytic rectification of these metals, with the exception of hafnium, has been studied by a number of investigators. Data are available for a wide variety of conditions, but the general effect is illustrated by the change of voltage with time at constant current. In this case, a characteristic curve is obtained which rises rapidly at first and then levels off or drops slowly with time, after reaching a peak. Below the maximum or critical voltage, a linear relation exists between voltage and oxide thickness for all the well-known valve metals (4).

Titanium has been anodically polarized at voltages up to 200 volts in phosphoric acid solution (5). The oxide layer which formed was shown to be identical with anatase. Later work under similar conditions showed the presence of a partly crystalline, partly amorphous oxide structure (6). Zirconium anodizes readily in dilute sulfuric acid with formation of a layer of ZrO_2 (3, 5). Columbium and tantalum have been reported to be similar in anodizing behavior. Columbium exhibits rectification (8), and presumably forms a layer of Cb_2O_5, analogous to the oxide Ta_2O_5 on tantalum (9, 10). Tungsten was shown to be intermediate between aluminum and tantalum in regard to rectification in solutions of mineral acids (7). Guntherschulze and Betz (11) showed that the oxide consisted of WO_3.

Experimental Procedure

Electrode Materials

The metals were commercial materials, except for zirconium and hafnium which were produced for the Atomic Energy Commission.

The zirconium specimens were obtained from two lots with different histories of treatment. The first consisted of rod which had been extruded from a bundle of crystal bar and then homogenized at 1400°C for 3 hr. As a result of this treatment, the texture of the rod was the same as for recrystallized cold-rolled zirconium (12). The second lot of material consisted of plates and blocks machined from arc-melted ingots. The ingots were cast from crystal bar in a helium atmosphere. The texture of this material was not investigated but was presumably random.

The zirconium was stated to be hafnium-free. The average analysis for other elements in weight per cent was as follows: Fe, 0.030; C, 0.030; N, 0.010; Ni, 0.005; Al, 0.004; Pb, 0.002; Cu, Mo, and

[1] Manuscript received November 3, 1952. This paper prepared for delivery before the Montreal Meeting, October 26 to 30, 1952.

Cr, all 0.001; Si, <0.005; Sb, <0.0005; Sn, <0.0005; W, <0.10. The spectrographic analysis for tungsten, which was probably present as inclusions, was not well defined. Other elements were below the limit of spectroscopic detection.

The hafnium was a section of crystal bar as prepared by the De Boer-Van Arkel process; an analysis was not available. The titanium was in the form of rod and sheet. The columbium and tantalum were rolled sheet 0.005 and 0.030 in. thick, respectively, while the tungsten was a rod ¼ in. in diameter.

Preparation and Procedures

All specimens were cleaned by wet grinding and polishing to 400 grit paper, followed by pickling. The titanium, zirconium, and hafnium were cleaned in a solution of 8 ml conc. HF (48%), 50 ml conc. HNO_3 (70%), and 50 ml distilled water. A mixture

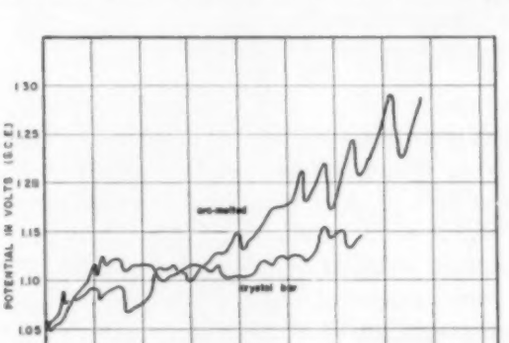

FIG. 1. Potential-time curves for anodic polarization of zirconium in 70% HNO_3, 1 ma/cm², 25 ± 1°C: potentials vs. saturated calomel. Both specimens had a randomly oriented texture.

of 1 part by volume conc. HF to 3 parts by volume conc. HNO_3 was used to clean the columbium, tantalum, and tungsten. It was found that if cleaning were not complete in the case of the group IVA metals, the residual oxide was a site for film breakdown. This was attributed to the presence of fluoride salts on these areas. The specimens varied in surface area from 1 cm² for the extruded zirconium rod to 27 cm² for the tantalum sheet. The extruded rod was mounted in Bakelite with the round cross section exposed to the electrolyte. The arc-melted zirconium specimens were anodized on the entire surface, using threaded rods of zirconium for contact. In other cases, the anodized zone was stopped off, using plastic tape and paraffin.

All the data are in terms of cell voltage except for Fig. 1, where the potential of the zirconium is referred to the saturated calomel scale. With this exception, the usual assumption was made that the voltage changes are a measure of the resistance of the oxide (3). The *IR* drop in solution, as measured by a calomel probe, was less than 15 mv under all conditions. Platinum gauze was used throughout as the cathode. The unpolarized potential of the platinum was about +1.10 volts vs. saturated calomel, and the polarized potential was about +1.05 volts. All concentrations of nitric acid are reported in weight per cent of HNO_3 in the solution, and the temperature was kept at 25 ± 1°C.

Voltage and current-time curves were measured on two Micromax recorders covering different voltage ranges. Color changes were noted and measurement was made of capacitance after anodizing. For the latter purpose, a General Radio Company Type 650-A impedance bridge was applied to the anodizing cell. The anodized metal and the electrolyte provided the plates of a condenser whose capacity was determined by the thickness and dielectric constant of the oxide layer (3). The reading

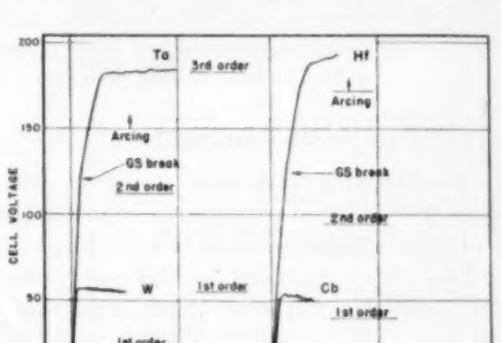

FIG. 2. Change of cell voltage with time in anodizing titanium, hafnium, columbium, tantalum, and tungsten, 1 ma/cm², 70% HNO_3, platinum cathode, 25 ± 1°C. The terms 1st and 2nd order indicate interference colors equivalent to air film thicknesses of 2500 and 5000 Å. The GS break is an inflection of the type noted by Guntherschulze (11). Spark discharge is visible above the point indicated.

was not affected by the platinum gauze which simply represented a very large capacity in series.

RESULTS

The data consist of a comparison of the voltage-time curves obtained in anodizing the six metals and a more detailed study of zirconium which was found to develop a low-resistance layer in contrast to the others.

Comparison of Anodizing Characteristics of Six Metals

The metals were compared by anodizing at 1 ma/cm². This current density was convenient since a voltage maximum (or critical voltage) was attained in 5 to 30 min.

The data are shown in Fig. 1 and 2. Each curve in Fig. 2 is a typical result of three trials. The re-

reproducibility of the maximum or critical voltage was ±1 volt for titanium and ±5 volt for hafnium, columbium, tantalum, and tungsten. In all cases except zirconium, the voltage rose rapidly at first and then leveled off, with interference colors appearing as noted on the figures. The lines marked 1st and 2nd order indicate the metallic blue hiatus at equivalent air thicknesses of 2500 and 5000 Å. These values were determined from the table of interference colors vs. air-film thickness as compiled by Rollett (13). The results are summarized in Table I where a comparison is given of the maximum voltages and specific capacitances.

The capacities were measured in the same solution at the peak voltage and after anodizing for 1 hr. An increase in capacity after the maximum voltage was attained was considered as evidence of film breakdown. Such a change could represent an increase in surface area or an increase in permeability of the film. The metals which showed the largest drop from the peak voltage also showed the largest increase in capacity.

Zirconium formed a black layer which showed no tendency to reach a limiting thickness. The capacity was too large for measurement before and after anodizing (>5μf/cm²). Interference colors were observed within the first hour but disappeared as the surface became darker. At 1 ma/cm², the voltage-time curve on the 300-volt scale was flat for times up to 16 hr. The voltage changes were of the order of millivolts, and it was necessary to employ a saturated calomel cell as reference. The open-circuit potential of the zirconium was not reproducible, but became steady as soon as current was passed. The initial polarized potential was very similar to that of platinum (approximately +1.10 volts). The potential then rose as film growth took place. Typical curves are shown in Fig. 1. Another specimen was anodized in this manner for a total of 30 hr. After 15 hr, the voltage began to fluctuate in a periodic manner until at 30 hr the variation was approximately 250 to 1250 mv in an interval of about 10 min.

Titanium formed an interference film, which soon reached a limiting thickness. Oxygen evolution occurred from the onset of anodizing in contrast to the other metals where the anodic efficiency was close to 100 per cent up to the critical voltage. Spark discharge was not observed in titanium when the peak was reached and current passed steadily. The film evidently underwent some breakdown as indicated by a drop in peak voltage.

Hafnium was similar to tantalum with a large critical voltage, pronounced sparking above a well-defined limit, and inflections (labeled GS breaks) of the type noted by Guntherschulze for tantalum (14). The hafnium crystal bar had a large-grained structure which was observed to influence the rate of oxide growth. The interference colors varied from grain to grain to above 170 volts where sparking set in. The resultant film destruction produced a dull gray surface with friable white oxide covering only certain distinct grains. The role of grain orientation has not been identified. At current densities below 0.5 ma/cm² a low-resistance film was also formed on hafnium. The contrast with zirconium, therefore, is not as great as the measurements at 1 ma/cm² would indicate.

Columbium and tungsten were very similar in response to anodizing and were intermediate between titanium and tantalum. The peak voltage was erratic, with larger fluctuations in the case of columbium. No spark discharge was visible with ordinary room illumination but is probably present (13).

In the case of tungsten and tantalum, it was possible to calculate the capacity from the peak voltages using the thickness/applied voltage ratios and dielectric constants as determined by Guntherschulze (11). From these, the calculated capacities were 0.37 and 0.07 μf/cm² for W and Ta, respectively. These values are in reasonable agreement with 0.42 and 0.08 μf/cm², measured after reaching maximum voltage (Table I). The limiting thicknesses are, therefore, 550 Å for W and 1500 Å for Ta.

TABLE I. *Characteristics of films produced by anodizing in 70% nitric acid at 25°C, 1 ma/cm², platinum cathode*

Metal	Time to reach maximum voltage (min)	Maximum voltage	Electrical capacity μf/cm²	
			At maximum voltage	After 1 hr
Ti	5	10	2.2	>5
Zr	—	—	—	>5
Hf	25	185	0.057	0.26
Cb	4	40	0.7	1.0
Ta	22	180	0.08	0.07
W	5	57	0.42	1.7

Zirconium in Various Concentrations of Nitric Acid

In most dilute electrolytes the behavior of zirconium is similar to the other five transition metals investigated. Solutions of dilute sulfuric acid, oxalic acid, borates, and potassium hydroxide showed a well-defined critical voltage. However, when a small percentage of nitric acid was added to these solutions, the maximum voltage was sharply reduced. It was found that with nitric acid the voltage-time curve was dependent on concentration to a greater degree than with any of the above anodizing media.

Changes in Voltage-Time Curves with Concentration

The effect of concentration of nitric acid was studied to determine the transition from the high-

to low-resistance behavior. The same experimental procedure was used, and only the concentration of the solution was varied. This work was done with the extruded zirconium which had been formed from compacted crystal bar. The circular cross section

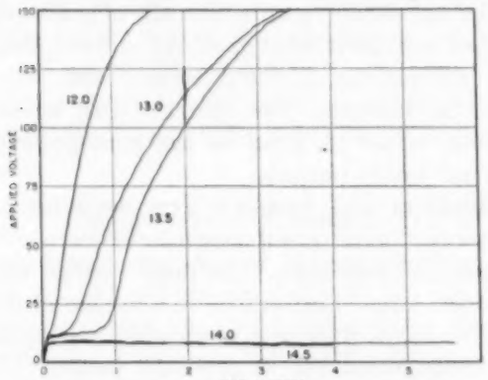

FIG. 3. Changes of cell voltage with time in anodizing zirconium [(11$\bar{2}$0) plane] at 1 ma/cm² in various concentrations of nitric acid (wt %). A platinum cathode was used with the bath at 25 ± 1°C.

Concentration of HNO_3 (wt %)	Rate of Film Growth	
	Low	High
10, 12	white breakdown product; dense white layer; sparse white layer; interference colors	
13, 13.5	yellowish-white or light grey	dark grey, flaking; fine white, powdery layer
14	Peeling; blue-grey	first to flake; thin friable layer
15	blue-grey	flaky and friable
70	black, hard, coherent	first to flake

FIG. 4. Extremes in surface appearance observed on zirconium anodized several hours at 1 ma/cm², 25°C in concentrations of nitric acid as indicated.

of this rod was exposed to the nitric acid after mounting in Lucite, polishing, and acid etching. Each specimen had an exposed area of approximately 1 cm² and was drilled and tapped at the back for contact.

The texture of this exposed section was determined by the Geiger counter spectrometer technique (15). It was found to consist predominantly of the (11$\bar{2}$0) plane. Extruded specimens with this plane exposed were used to obtain all the data of Fig. 3, 4, 5, and 6. Therefore, these particular results are not necessarily representative for zirconium of random orienta-

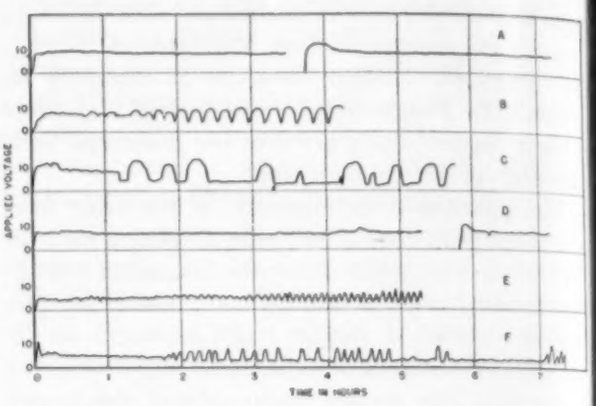

FIG. 5. Periodic variations in cell voltage when anodizing zirconium [(11$\bar{2}$0) plane] in various concentrations of nitric acid (wt %). 1 ma/cm², 25 ± 1°C, Pt Cathode. Curve A, 14.5%; curve B, 15.0%; curve C, the same as B after interruption; curve D, 15.5%; curve E, 20.0%; curve F, the same as E after interruption. The periodic effect was not consistently observed in the critical concentration region as indicated by curve D.

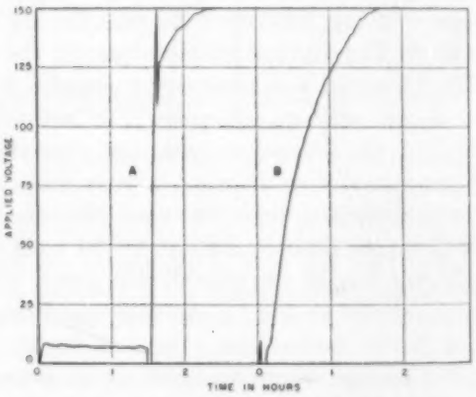

FIG. 6. Curve A: the effect upon the voltage-time curve of a temporary increase in current density from 1 ma/cm² to 10 ma/cm² for 1 min (steep pip) and return to 1 ma/cm² (rising to 150 v). Curve B: the effect upon the voltage-time curve of initially using 1*N* H_2SO_4 as electrolyte for 1 min (initial pip) and then substituting 15.5% HNO_3 after a short interruption. With exceptions as noted, both curves were measured in 15.5% HNO_3 at 1 ma/cm², 25 ± 1°C with a platinum cathode.

tion. The remaining data (Fig. 1, 2, 7; Tables I and II) were taken with specimens presumed to have a random texture from their method of preparation (arc-melting and casting).

The transition phenomenon for the (11$\bar{2}$0) orientation is shown in Fig. 3 and was observed to occur in the range 13.5–14.0 per cent. Above and below

this concentration interval, the pattern of oxide formation was significantly different.

Variations in Rate of Film Growth

Certain areas of each section developed thicker films than others, and the appearance was noted after each experiment. In the more dilute nitric acid (10 and 12%), the film developed with clear interference colors. As the voltage increased, these films were gradually broken down with the formation of white oxide which replaced the colored areas. The white product appeared first on the thinner films, and last on the thicker films as determined by interference colors. This is believed to be a type of dielectric breakdown which is promoted by nitric acid (as compared to sulfuric and oxalic acid of equivalent concentration).

In the intermediate range where the plateaus occur (13 and 13.5%), the oxide appeared blue-gray

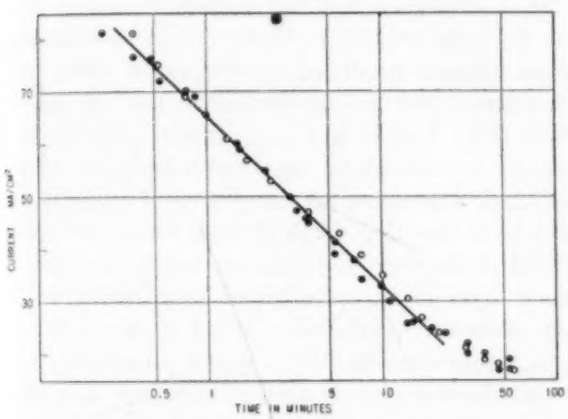

FIG. 7. Current density vs. log time for a zirconium specimen anodized at 5 v vs. a platinum cathode in 70% HNO_3, 25°C. The results of three experiments are given.

in color. The thin film areas developed an even yellowish-white layer similar to the breakdown product observed in the 10 and 12 per cent acid. The thicker films were dark gray in the plateau region, but with the subsequent voltage increase, the layer was disrupted and began to flake with the formation of white oxide beneath it. The dark-gray layer was evidently permeable and breakdown occurred at the metal-oxide interface. In more concentrated acid the oxide became black and opaque. Some interference colors could be observed initially if the current density was below 1 ma/cm².

The extremes of surface appearance are illustrated by schematic cross sections in Fig. 4.

Periodic Effects

The formation of the black oxide was found to be accompanied by periodic variations in resistance as shown in Fig. 5, where a number of voltage-time curves are presented for acid concentrations above 14.0 per cent. These data were taken under the same conditions as those in Fig. 3 with details as given below. Curve A was taken in 14.5 per cent acid and was essentially flat after the initial rapid rise. The current was interrupted for a short period and then restarted. As indicated, the curve rose to a higher value and then returned to the original peak. Curve B was taken in 15 per cent acid and showed a periodic fluctuation until the current was interrupted. The specimen was not removed from solution, and the current was restarted after 65 hr with the result shown as curve C. The fluctuations occurred again but were larger and less regular. Periodicity was not observed in curve D taken in 15.5 per cent acid but was found in 20 per cent and, as noted previously, in 70 per cent acid. The results in 20 per cent acid are shown in curves E and F. Curve F is a continuation of E after an interruption of 13 hr. A change in the type of fluctuation is again evident.

TABLE II. *Characteristics of the anodizing of six zirconium specimens in 70% nitric acid*

Spec. No.	Current density at 10 min (ma/cm²)	Slope $-I/\log t$ (ma)	Efficiency of oxidation, %	Degree of flaking (% of area)
1	33.8	31.1	28.4	1<
2	21.0	27.7	37.7	1
3	18.5	34.6	45.2	5
4	32.3	26.3	40.6	20
5	24.0	36.5	41.7	80

Irreversible Formation of the High-resistance Layer

Two further effects were noted and are shown in Fig. 6. Curve A demonstrates the effect of a temporary increase in current density from 1 to 10 ma/cm². This curve was begun in 15.5 per cent acid and followed a normal course. The current was interrupted for 2 min at the break and then was renewed at 10 ma/cm² for 1 min. It was then dropped back to 1 ma. As may be seen, the current increase produced a surface change equivalent to a lower acid concentration. Curve B was started using 1*N* sulfuric acid and the voltage was allowed to rise to the same peak obtained in 15.5 per cent HNO_3. The current was then interrupted (for 3 min) and the electrolyte was changed to 15.5 per cent HNO_3 after rinsing the system with distilled water. Upon renewing the electrolysis, the voltage rose to a new peak as shown.

The high-resistance film is evidently formed irreversibly. When a higher voltage was imposed on a specimen on which a black oxide layer had been formed, a thin film exhibiting interference colors appeared underneath, and the black layer was forced

off the surface. However, when zirconium with a low-resistance film was allowed to dry in air, the black oxide acquired a high resistance and was very difficult to remove by the same treatment after reimmersion.

Anodizing at Constant Voltage in 70% Acid

A series of arc-melted specimens were anodized at 5 volts direct current in 70 per cent HNO_3 and the current measured as a function of time. This material was not cold-worked and was presumed to have a random texture. At higher voltages (approximately 10 volts, and above), the oxide became gray and developed a higher resistance with smaller net currents than were obtainable at 5 volts. The low-resistance layer was studied in more detail since it is less typical of anodic phenomena. The bath was stirred in all these measurements.

At 5 volts, the surface of the metal darkened rapidly with little or no appearance of interference colors. The average weight gain was 2.50 mg/cm^2 at the end of 1 hr. The thickness of ZrO_2 calculated from this value is 0.017 mm using 5.68 g/cm^2 as the density of ZrO_2 (16). At 10 ma/cm^2 (the average current at the end of one hour) the specific resistance of this layer was approximately 3×10^5 ohm/cm. This may be compared with a resistance of 0.677×10^{12} ohm/cm produced by anodizing in 0.1*N* H_2SO_4 (11). In most cases, the coating tended to flake to a varying extent after 25 min. The surface features of the specimen were completely preserved up to the point of flaking. After one hour, the flaked area covered nearly the entire surface of one specimen, while it was hardly noticeable on another. The spalling was accompanied by a sharp "pinging" noise, but this process did not seem to affect the current-time curve. The flakes were collected in order to determine the total weight gain and efficiency of oxidation. The area under the current-time curve was measured to determine the coulombs passed. Further flaking was sometimes observed upon standing in water overnight, but not upon standing in air. The residual coating was found to be hard and difficult to remove. The flakes turned white upon heating below red heat in air.

A plot of the data for three separate trials on one specimen is shown in Fig. 7. The points were taken from a chart record and are plotted as current density vs. log time. The semilog dependence is seen to hold for the initial part of the curve. The results for four additional specimens are summarized in Table II.

There was no evident correlation of slope and degree of flaking with any other variable. The results could not be related to slight variations in composition. This point was checked further on five additional specimens. The only evident relationship is between current density and efficiency of oxidation. The current was highest when the efficiency was low and vice-versa. The grain size of this material was variable and it possible that grain orientation caused some of the variation in results.

Oxide Structure

Samples of the anodic products were examined by x-ray diffraction. These included the white oxide produced in dilute nitric acid (below 10%), the black flakes produced at 5 volts in 70 per cent acid, and the same flakes after heating in air to convert them fully to white oxide. All three patterns indicated monoclinic ZrO_2 with possibly some cubic phase present in the black coating before and after heating. This may have been nitride or carbide present as an impurity.

Discussion

It is suggested that the observed changes in the anodic layer are due to variations in the number of anion defects produced in the oxide. ZrO_2 has a structure which favors the production of such defects (17). According to Cubicciotti (18) the oxide coating on zirconium can vary from pure white to jet black depending on the degree of oxidation. On this basis the thin films of high resistance are believed to be close to stoichiometric oxide while the black layer is an anion-defect semiconductor. The low efficiency of oxidation in the presence of nitric acid (approximately 40%) would presumably favor the production of such a defect structure. The reason for this lowering of efficiency is not clear.

The "step," observed in the transition zone, is believed to be an initial growth of low-resistance oxide followed by the formation of an underlying high-resistance film. This may be the result of a gradual depletion of nitric acid at the metal-oxide interface. The effect of orientation is an indication that diffusion is anisotropic at the growing interface or through the oxide.

From the Pilling-Bedworth ratio (19), the hardness, and noise on spalling, one may conclude that the layer is under a large internal stress. The diffuseness of lines of the x-ray pattern indicates strain or a very fine state of subdivision of the layer. The anodic behavior of zirconium is similar in some respects to the anodic behavior of silver in solutions of HCl (20). Similarities in electrode mechanism may also exist.

Acknowledgment

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Any discussion of this paper will appear in the June 1954 issue of the JOURNAL.

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The Reaction of Silver Alloys with Sulfur in Mineral Oil

I. Kinetics[1]

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ABSTRACT

The rates of reaction between 33 solid solution alloys of silver and sulfur in mineral oil were studied over a time interval of 1000 hr. The typical reaction course consisted of two phases: an initial rapid reaction similar to unalloyed silver; preceded by a linear steady-state phase. The reaction rate (slope of straight line) decreases with concentration of alloying element up to 10 atomic per cent, after which there is little change in rate. The identity of the alloying element is of minor importance. The exceptions to the general behavior are silver-thallium alloys which react much like unalloyed silver throughout.

Introduction

The tarnishing of silver and of alloys of silver in sulfur-containing atmospheres has received considerable attention in the past. However, there has been published very little quantitative information tracing the course of reaction of silver alloys with sulfur.

The mechanism by which metallic silver reacts with elemental sulfur in mineral oil at temperatures from 40° to 92°C has been clarified (1). By consideration of a diffusion process mathematically formulated by Wagner (2), it was shown that the rate of reaction at these low temperatures is controlled by diffusion of sulfur through the oil solution to the surface of the metal strip. Several preliminary measurements on the rate of reaction of silver alloys under comparable experimental conditions gave evidence of a much lower rate, and suggested that the mechanism of reaction in the case of the silver alloys was different from that controlling the rate of reaction of silver itself.

The purpose of this investigation was to establish, and, if possible, to give theoretical significance to the kinetics of the reaction between silver alloys and sulfur in mineral oil. This special case is simpler than many corrosion systems of technological interest. The metal and the reactant are isolated in an inert environment, and the interpretation of the results should not be complicated by extraneous influences, e.g., moisture. Therefore, the observations with regard to the reactivity of the particular metal surfaces and the influence of the tarnish films which are formed should be of a fundamental nature.

A further objective of this work was to seek an alloy of silver resistant to attack by sulfur in mineral oil, although it was recognized that "tarnish resistance" might be based on rather arbitrary standards. A review of the literature on tarnish-resistant alloys of silver makes at least two generalizations possible. The first is to the effect that an alloy containing a high percentage of silver, i.e., about 90 per cent, is not immune to attack by sulfur by virtue of its own lack of reactivity. [This is altered if the surface is covered with an oxide film (3, 4).] The second generalization is one that may be made after the survey of almost any series of corrosion experiments in different media. That is, that the type of testing atmosphere employed may drastically affect the observation to be made as to the effect of a given element in altering the reaction rate of a reactive metal. Many of the previous investigators whose work is described in the literature used aqueous testing solutions or air contaminated with sulfur compounds. The study reported here was carried out in mineral oil containing elemental sulfur.

Experimental

A total of 33 binary alloys of silver (Table I) were prepared by standard metallurgical practice with chemically pure metals. The additions of the various elements were so limited that the final compositions fell within the solid solution region (5). After casting, rolling, and annealing, the alloy strips were ground and polished finally with fine (Behr-Manning 3/0) emery paper. The polished strips were swabbed with benzene, then with acetone, and then dried.

After an electrolytic etch in potassium cyanide solution (50 g/l), samples of the alloys were examined microscopically for the possible existence of second phases. The examination did not reveal any

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phase present other than the silver-rich phase expected from the composition and knowledge of the thermal phase diagram.

Electron diffraction examination of the surfaces of the various alloys gave, in general, patterns similar to that of silver. One would expect the alloys to have lattice parameters slightly different from that of silver. However, the electron diffraction measurements by the reflection technique are not of sufficient precision to detect these small distortions. An exception was the 24.4 per cent Zn alloy which gave a pattern, probably due to a surface contaminant, that was not identifiable.

The technique of following the course of reaction was very similar to that previously reported (1). An alloy strip was suspended in a 125-ml volume of a reaction solution, which consisted of 120 ml of mineral oil and 5 ml of a solution of elemental sulfur dissolved in benzene, at 60°C (±0.2°C). The sulfur solution contained 2.00 mg/ml sulfur. After a given period, the sample was withdrawn from the

TABLE I. *Alloys of silver studied*

Alloying element	Weight % in alloy
Al	0.4, 1.6, 4.0
Sb	1.8, 3.8, 5.6
Pb	1.2
Cd	2.0, 15.0, 19.8, 30.0
In	3.2, 6.2, 9.4, 11.8, 15.3
Mg	0.4, 0.8
Pd	5.1, 10.2, 19.8
Mn	2.1, 4.3, 9.2
Sn	2.1, 3.8
Zn	5.1, 9.6, 12.6, 19.0, 24.4
Tl	2.9, 5.9

reaction solution, allowed to stand in thiophene-free benzene for 48 hr, rinsed in benzene and acetone, dried, and weighed. After this treatment, the sample was replaced in a new solution of the same concentration as originally used. This treatment was repeated for various time intervals so that weight-gain measurements up to times of 1000 hr were obtained. Interruption in the course of reaction did not materially effect the final weight gain. Samples treated for a single time interval of several hundred hours and those treated in several time intervals of equal total time gave reaction rates which agreed within experimental error. The gain in weight observed following successive reaction times was related to the measured (projected) area, and the data were expressed in terms of milligrams gained per cm^2 of area, W.

Treatment of Data

Values of W were plotted against the appropriate reaction time in hours, t. The data were analyzed to determine whether the reaction followed a linear, parabolic, or logarithmic pattern, as the adherence to one of these laws would be suggestive of the mechanism of the reaction. Of these the parabolic law

$$W = k_1\sqrt{t} \qquad \text{(I)}$$

has been given considerable theoretical treatment (6). The linear relationship

$$W = b + k_2 t \qquad \text{(II)}$$

has been discussed by Vernon (7) and the logarithmic

$$W = a + k_3 \log t \qquad \text{(III)}$$

by several workers (8). These three laws have demonstrated their usefulness in the interpretation of the kinetics of metal-surface reactions.

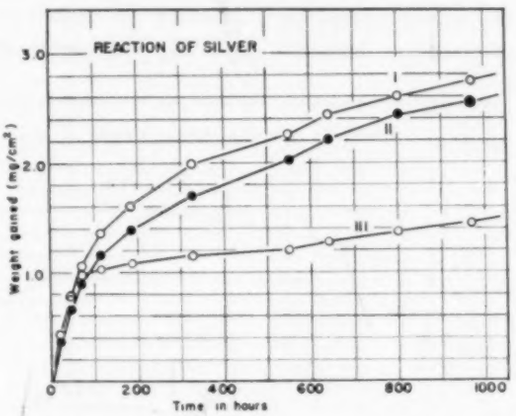

FIG. 1. Reaction of unalloyed silver with sulfur in oil. Sulfur was replenished at times corresponding to each of the circles.

RESULTS

Kinetics of Reaction of Unalloyed Silver

The data for the reaction of unalloyed fine silver (99.9%) with sulfur in mineral oil are shown in Fig. 1. Sulfur content was restored to its original concentration at the time intervals indicated by the individual points. This concentration was 2.5×10^{-3} m/l, equivalent to a strip weight gain of 0.55 mg/cm^2.

The behavior of unalloyed silver exhibits several characteristics at variance with that of the silver alloys discussed below. The most outstanding lies in the continual rapid growth of the film (or scale) on silver as long as an adequate supply of sulfur is maintained. Moreover, the reaction rate is dependent on the sulfur concentration. The dependence of rate on sulfur concentration during the early stage of the reaction has been related quantitatively (1) to sulfur diffusion, the rate-determining step. This is a factor after a thicker film has developed, but it appears that other influences are involved when the

film attains thicknesses of the order of 50,000 Å. The reaction product at this stage is blistered and can be flaked off easily. It is likely that a film diffusion process hindered by cracks running parallel to the surface of the strip, as proposed by Evans (8), might account for a rate lower than that expected if sulfur diffusion in solution were still the rate-determining step.

Measurements made at 100 hr or less are quite reproducible from strip to strip. However, the precision decreases during the later stage of the reaction. While curves I and II in Fig. 1 are typical, curves similar to III were sometimes encountered for no explainable reason.

Kinetics of Reaction of Silver Alloys

In reporting the results of measurements made on the silver alloys it is possible to make several generalizations because, with the exception of the

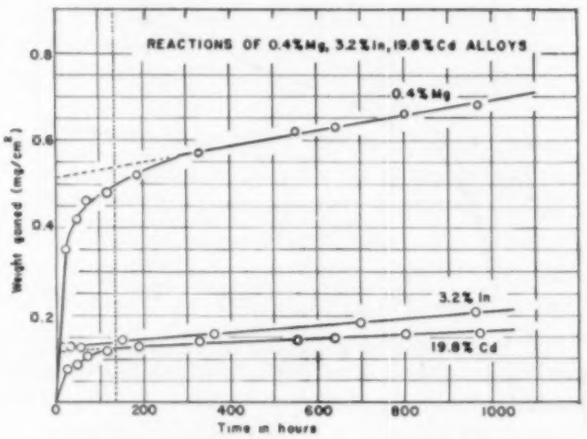

FIG. 2. Reaction of silver alloys with sulfur in oil

silver-thallium alloys, the reaction curves (W vs. t) for all of the alloys are quite similar in shape.

The data for the 0.4 per cent Mg, 3.2 per cent In, and 19.8 per cent Cd alloys are plotted in Fig. 2, and the manner in which the sulfide film grows on these alloys is typical of all but the thallium alloys. The entire reaction may be broken down into two distinct phases, each with a different rate-determining step. During the first portion of the reaction (to left of the dotted line in Fig. 2) the sulfide film is built up so that the reaction reaches the steady-state condition which characterizes the second phase of the reaction. The latter occurs after about 100 hours' reaction time, and the linear curve from then on represents film growth. During the first few hours the growth of the film is rapid, much like unalloyed silver. Exceptions are the higher alloys of zinc (19.0%), cadmium (30.0%), palladium (19.8%), and indium (15.3%). Curves for these conform to linearity after growing to thicknesses corresponding to 0.071, 0.033, 0.047, and 0.074 mg/cm², respectively. Thus, these alloys follow the simple straight line relationship from almost the start of the reaction.

No attempt is made to reproduce the entire mass of reaction data, but Table II gives a summary of intercepts and slopes of the straight lines. The latter represent the steady-state scale growth. Slopes for the steady-state condition for the various alloys are plotted against the atomic percentage of the alloying element in Fig. 3. From this plot it may be concluded that, as the percentage of the alloying element in the silver base alloy is increased up to 10 atomic per cent, reaction rate decreases. Alloys with more than 10 atomic per cent of the alloying element exhibit a low rate of reaction which seems to be insensitive to the further addition of alloying element. Departure of individual points from the curve indicates that this is only a rough correlation.

There is no obvious relationship between the slope of the straight line (a measure of the rate of reaction) and the thickness of the film which must grow be-

TABLE II

Alloy	Weight %	Atomic %	Slope of straight line × 1000-"k_2" (mg. cm^{-2} hr^{-1})	Intercept of line "b" (mg cm^{-2})
Ag-Al	0.4	1.7	0.21	0.61
	1.6	6.1	0.13	0.063
	4.0	14.3	0.19	0.065
Ag-Sb	1.8	1.6	0.084	0.40
	3.8	3.4	0.096	0.37
	5.6	5.0	0.095	0.38
Ag-Pb	1.2	0.63	0.16	0.67
Ag-Cd	2.0	1.9	0.15	0.20
	15.0	14.5	0.058	0.13
	19.8	19.1	0.056	0.096
	30.0	29.1	0.032	0.033
Ag-In	3.2	3.0	0.085	0.13
	6.2	5.84	0.049	0.18
	9.4	8.88	0.029	0.12
	11.8	11.2	0.028	0.10
	15.3	14.5	0.021	0.074
Ag-Mg	0.40	1.8	0.13	0.55
	0.8	3.5	0.10	0.66
Ag-Pd	5.1	5.2	0.13	0.11
	10.2	10.3	0.037	0.044
	19.8	19.9	0.017	0.047
Ag-Mn	2.1	4.0	0.19	0.37
	4.3	8.1	0.10	0.16
	9.2	16.6	0.22	0.14
Ag-Sn	2.1	1.9	0.091	0.15
	3.8	3.5	0.047	0.11
Ag-Zn	5.1	8.2	0.063	0.15
	9.6	14.9	0.067	0.089
	12.6	19.2	0.065	0.074
	19.0	28.0	0.065	0.071
	24.4	34.7	0.11	0.013

fore the film adheres to the linear relationship. The importance of this is realized when it is remembered that, if the rate is controlled by diffusion through a uniform film, the reaction rate would be inversely proportional to the film thickness.

During the first stage of reaction, the rate is dependent on the concentration of sulfur in solution, but during the steady-state scale growth period it is not, as illustrated by Fig. 4 for the 3.8 per cent Sb alloy with two different sulfur concentrations. After 24 hours, the curves trace each other within

above. These alloys require formation of an exceptionally thick sulfide film before they follow the linear reaction law. It is not surprising that both the linear and logarithmic equations may be used to treat the experimental data. The logarithmic equation may well trace a reaction over its whole course, while a certain part of the actual corrosion data in the latter part of the reaction might follow a straight line. In our present state of knowledge there is no widely accepted theoretical explanation for a logarithmic reaction curve for thick films, so there

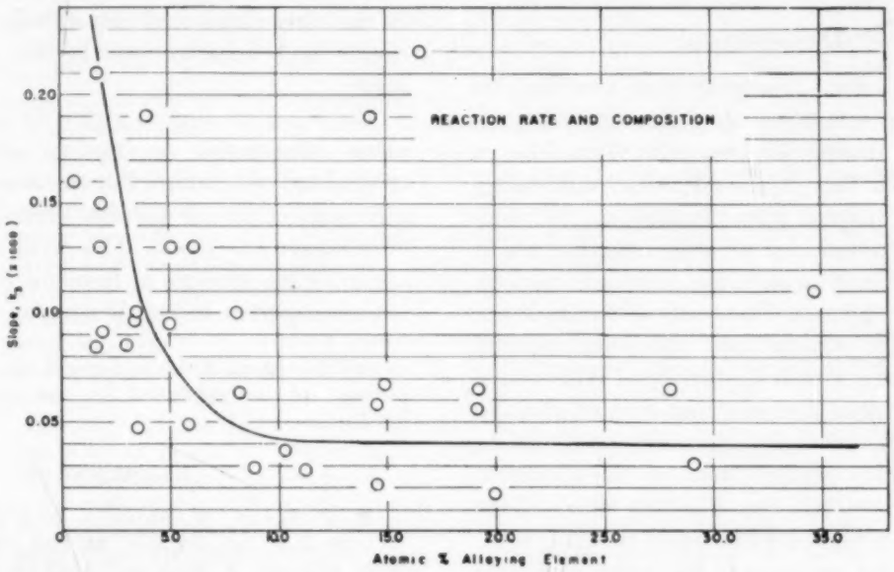

FIG. 3. Relationship between rates of reaction of silver alloys (slopes of the linear portions of the curves in FIG. 2) and atomic percentage of alloying element in solution in silver.

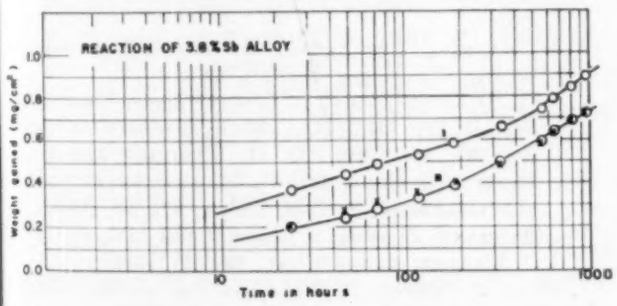

FIG. 4. Reaction of a 3.8% Sb-Ag alloy with sulfur in oil at two sulfur concentrations. Curve I—5.0×10^{-3} moles/liter; curve II—2.5×10^{-3} moles/liter.

experimental error. The X's represent the weight-gain values which went to make up the upper curve, reduced by an amount equivalent to the difference in weight gain during the initial reaction in solutions of the two concentrations. This behavior is typical of other alloys.

The data for 1.8, 3.8, 5.6 per cent Sb alloy, the 1.2 per cent Pb alloy, and the 0.4, 0.8 per cent Mg alloys are best represented on an empirical basis by a logarithmic relation such as the third equation

would be no object in reporting the parameters of the equations that fit the reaction data of several of the above alloys.

As was stated above, the reaction course of the thallium alloys represents exceptions to the general behavior of the group. In developing the experimental reaction conditions, an attempt was made to have present throughout the reaction an excess of elemental sulfur so that contributary effects of sulfur diffusion through solution would be minimized. This was not realized during the early stages of the reaction (under 100 hr) with many of the alloys, and it may be shown that sulfur diffusion in solution is rate-determining at the outset of the reaction. But, during the later stages of the reaction, the sulfur consumed is usually of the order of 5–10 per cent of the available sulfur. Unalloyed silver, on the other hand, reacts in 100 hr with a considerable amount of the sulfur used in these experiments, and forms a heavy scale. The behavior of unalloyed silver is approximated by silver-thallium alloys, as is demonstrated by the following comparison of data.

Reaction time, hr	Wt gain (mg/cm²) 2.9% Tl-Ag	Ag
18.25	0.15	0.18
36.25	0.29	0.37
55	0.43	0.52
120	0.68	0.77
231	0.89	1.01
419	1.13	1.28
539	1.17	1.33
1019	1.27	1.43

This behavior should be contrasted with the curves in Fig. 2 which have been presented as typical of the majority of the alloys.

Discussion

The curves in Fig. 2 suggest that two distinct rate-determining influences may be operating at different stages during the reaction. This idea is not novel (9). In fact it should occur with many processes under normal circumstances if the reaction is allowed to continue at great length, but, in practice, it is difficult to separate a surface reaction into its separate phases. The part of the reaction of concern is the steady-state condition reached when a film attains a certain thickness. With alloys containing more than 5 atomic per cent of alloying element this thickness varies from 2000 to 20,000 Å, dependent only to a minor extent on the nature of the alloying element present. For this steady-state condition to be achieved with alloys of lead, antimony, and magnesium, films of the order of 37,000 to 74,000 Å thick must be developed. The kinetic data for these three alloy systems are represented quite well, although empirically, by logarithmic curves. Whether or not this is related to the thickness of film required to reach a steady reaction state which other alloy systems reach at a lower film thickness cannot be stated now.

The relationship between the slope of the straight line and the atomic percentage of the alloying element shows that the reaction rate drops to a low value as the amount of alloying element is increased. The 10 atomic per cent value seems to be critical in that it must be attained for most of the systems before a low reaction rate is achieved. Once attained, there is little further decrease in rate on further addition of alloying element. The antimony alloys are exceptions to this general trend.

In a system of this type, a "tarnish resistance" alloy may well be defined as an alloy which is characterized with a low value for the intercept and slope of the straight line representing the steady-state condition. Alloys containing higher percentages of cadmium, indium, palladium, and zinc would fall within this definition.

The reaction of silver-thallium alloys with sulfur is different in type from that of the main body of alloys. The reaction data follow much the same pattern as that of unalloyed silver, and it may be concluded that the same rate-determining influences are operative. These influences appear to be the diffusion of sulfur through the oil solution to the metal strip in the early stage, and film diffusion complicated by cracks and imperfections in the film in the later stage.

The reaction curves given do not provide sufficient information to outline unequivocally the mechanism of reaction. For this reason an exhaustive examination of the tarnish films in various stages of reaction was made. This work and the interpretation of the kinetics in terms of the diffusion process are reported in another paper (10).

Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the JOURNAL.

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Mechanism of Reaction of Aluminum and Aluminum Alloys with Carbon Tetrachloride[1]

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ABSTRACT

Further observations on the Al-CCl_4 reaction show that vacuum treatment of aluminum decreases the induction time from 70 to about 5 min. This may be a consequence of removing water and perhaps also oxygen from the oxide film. Vacuum treatment has no effect on the long induction time for 2.43 per cent Mg-Al alloy.

Corrosion products in CCl_4 reduce to zero the induction time of pure aluminum. It was found that $AlCl_3$ is responsible, and that ferric chloride acts similarly. These chlorides, however, have no effect on the corrosion rate.

Reaction of aluminum with carbon tetrachloride vapor is similar to its behavior in boiling liquid, the induction time and corrosion rates being approximately the same.

It is concluded that reaction is initiated by formation of active free radicals or atoms whose formation is accelerated with time, until the rate of generation equals the rate of destruction. The corrosion rate is then constant. Oxygen and water, whether in the solvent or in the aluminum oxide film, increase the induction time by reacting with free radical species responsible for initiating the reaction. Various organic compounds are corrosion inhibitors for the same reason. Alloyed magnesium presumably also reacts preferentially with free radical species, thereby prolonging the induction time independent of water or oxygen. $AlCl_3$, on the other hand, decreases the induction time, presumably forming a complex which dissociates into free radical species.

It is proposed that the free radical $\cdot CCl_3$ and the complex $CCl_3^+[AlCl_4]^-$ take prominent part in the chain reaction producing the observed major final corrosion products C_2Cl_6 and $AlCl_3$. Side reactions also occur, as is common with organic reactions of this type. HCl increases the corrosion rate by reaction with aluminum to form AlCl plus active H, the latter in turn reacting with CCl_4 to form $\cdot CCl_3$ and again HCl. $AlCl_3$ is hydrolyzed by water to form HCl; this explains why a small amount of water in CCl_4 can effectively increase attack after the induction time is exceeded.

Alloys containing manganese or magnesium react rapidly after the induction period, then more slowly, finally reaching a limiting weight loss. Their behavior, unlike pure aluminum, is caused by a protective reaction-product layer forming only after corrosion products reach a minimum concentration in CCl_4. The limiting weight loss depends, therefore, on the ratio of CCl_4 volume to area of aluminum exposed. It is also dependent on alloy composition. By analysis, the protective film is either mostly aluminum chloride with smaller quantities of complexed lower halides of aluminum, or a complex of aluminum chloride with various chlorinated hydrocarbons.

INTRODUCTION

Previous investigations (1) of the reaction of aluminum with boiling carbon tetrachloride showed that an induction time precedes rapid reaction. The induction time is increased by H_2O, CS_2, or O_2 in the solvent, and is decreased by corrosion products, while nitrogen and dry HCl have no effect. Once the induction time has elapsed, water and dry HCl increase the corrosion rate, but O_2 and N_2 have no effect. Some alloying elements increase the induction time, with magnesium additions being more effective than manganese additions. Unlike pure aluminum, corrosion of alloys may be stifled after initial attack.

In this paper, a reaction mechanism is proposed, the cause of the induction time is treated further, and the effects of alloying elements on the induction period and corrosion rate are discussed.

PROCEDURE

High purity boiling carbon tetrachloride (sulfur free) was used in obtaining the present data. The procedure for further solvent purification, specimen surface preparation, and the apparatus used for weight loss in the liquid phase are the same as those reported previously (1).

Analysis of the aluminum, kindly provided by the

[1] Manuscript received March 9, 1953. This paper was prepared for delivery before the Wrightsville Beach Meeting, September 13 to 16, 1953.

Aluminum Company of America Research Laboratories, is given in Table I.

Results

Effect of Vacuum Treatment

Although oxygen was shown to increase the induction time, its possible presence in CCl_4 is not the inherent cause of delayed reaction. This was proved by immersing weighed specimens of pure aluminum in CCl_4 previously boiled for some time in the presence of purified nitrogen, and noting continuation of induction period. The thickness of oxide on aluminum is not primarily responsible, because anodizing had a relatively small effect, as did heating aluminum at 235°C for several hours. Also, alloys of aluminum with magnesium have a much longer induction time than pure aluminum (in some instances by a factor of 30), even though the oxide film on such alloys is not expected to be correspondingly more protective. Furthermore, addition of aluminum chloride to CCl_4 decreased the induction time for pure aluminum, whereas HCl gas, which might be expected to react with the oxide film, had no effect.

To shed additional light on this situation, specimens of 99.99 per cent Al, 3S(1.22% Mn), 52S(2.43% Mg), and 54S(3.44% Mg) alloys were heated at 400°C in vacuum (10^{-3} mm) for 7 hr. The specimens contained in glass tubes were sealed while under vacuum and transferred to an air-tight transparent box fitted with rubber gloves. After the box was flushed thoroughly with nitrogen, which was previously dried over liquid air, the tubes were broken and the specimens transferred to dry CCl_4. The flasks containing the specimens were then transferred to hot plates and the induction time measured. For 99.99 per cent Al and 3S, the time was reduced from the normal value of about 70 min and 120 min, respectively, to about 5 min. The times for 52S and 54S alloys, however, were not appreciably altered.

Vacuum treatment of this kind might be expected to crack or otherwise damage the oxide film and thereby account for the shorter delay in reaction of aluminum with carbon tetrachloride. If this mechanism is accepted, it is difficult to understand why the oxide films on magnesium alloys are not damaged similarly.

An alternative explanation is that water, and perhaps oxygen also, are removed from the oxide film. Heat-treatment in vacuum, as described above, is adequate to drive out moisture from the oxide film, according to previous investigations (2). Since both moisture and oxygen have been found to increase the induction time, it is not improbable that removing water and adsorbed oxygen from the oxide film at the metal interface would decrease the induction time. This still leaves the necessity for explaining lack of effect on the magnesium alloys, a question which is treated again later.

TABLE I. *Composition of aluminum alloys*

Alloy	Cu	Si	Fe	Mn	Mg	Cr
	%	%	%	%	%	
99.99	0.0004	0.0019	0.0031	0.001	0.0005	N.D.*
3S-H14	0.16	0.25	0.63	1.22	—	—
N	0.006	0.002	0.002	1.30	0.001	—
B50S-0	0.029	0.15	0.44	0.022	1.09	0.004
G	0.009	0.002	0.003	0.001	1.01	—
52S-H34	0.04	0.08	0.16	0.02	2.43	0.23
54S-H34	0.003	0.08	0.11	0.004	3.44	0.22

* N.D.—not detected.

Effect of Corrosion Products and Various Metal Chlorides

To examine in greater detail than before the effect of corrosion products on the induction time and corrosion rate of high purity aluminum, one gram of metal cut into small pieces was reacted to completion in 250 ml of boiling distilled CCl_4. Weighed specimens were then immersed in this solution and the weight loss determined as a function of time.

It was found that corrosion products in this amount decrease the induction time to zero (Fig. 1). However, they have no effect on the corrosion rate, which is the same value (40,000 mdd) as that reported previously (1) for high purity aluminum in carbon tetrachloride of similar water content.

The question arises as to which component of the corrosion products is responsible for decreasing the induction time. It has been demonstrated and confirmed that the main reaction is $2Al + 6CCl_4 \rightarrow 2AlCl_3 + 3C_2Cl_6$ and, hence, either aluminum chloride or hexachlorethane may be accountable. Table II lists weight loss data for 3-hr exposure tests in CCl_4 to which various additions have been made. Columns (A) and (B) are duplicate determinations, each value being the average weight loss for two specimens. The data show that aluminum

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chloride reduces the induction time, not hexachlorethane.

To determine whether other metal chlorides are also effective, anhydrous chlorides of iron, copper, and manganese were prepared by reacting the metal with dry chlorine gas in a Pyrex tube. The iron and copper chlorides were distilled directly into CCl_4. The manganese chloride was dropped from the tube into CCl_4 in a stream of dry nitrogen.

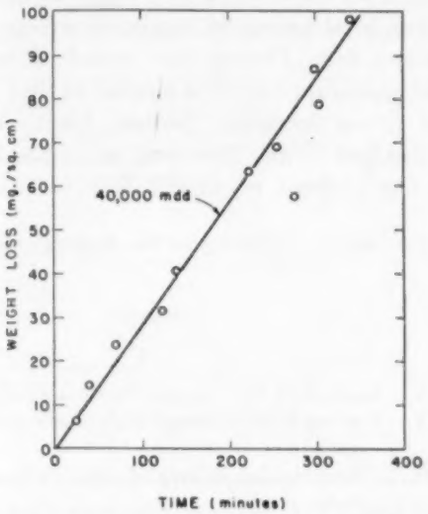

FIG. 1. Weight loss as a function of time for 99.99% aluminum in CCl_4 containing corrosion products from 1.0 gram of 99.99% aluminum.

TABLE II. *Effect of components of corrosion products on the corrosion of 99.99% aluminum in boiling, distilled carbon tetrachloride*

Addition to 250 ml distilled CCl_4	Weight loss (mg/cm^2/3 hr)	
	(A)	(B)
Nothing added	33.1	34.8
7 grams C_2Cl_6	28.1	32.0
Saturated with anhydrous $AlCl_3$	56.6	54.3
Corrosion products from 1 gram of Al	55.2	53.3

Table III shows that ferric chloride acts in a manner similar to aluminum chloride. The manganese and copper chlorides have no large effect, if any.

Effect of Alloying Components

Corrosion of 1.2 per cent Mn-Al *alloy.*—The behavior of commercial 3S aluminum (1.22% Mn) is different from high purity aluminum in that, after pronounced reaction occurs at a rate comparable with that of 99.99 per cent aluminum, the corrosion rate falls to a small value (Fig. 2). In 250-ml distilled carbon tetrachloride, the weight loss-time plateau is reached after a metal weight loss of 48 mg/cm^2. This weight loss is hereafter called the "limiting weight loss."

Three mechanisms can be postulated to explain why 1.22 per cent manganese in aluminum causes this marked difference in reaction behavior.

1. Manganese reaction products act as inhibitors or catalyze the formation of reaction inhibitors.

2. Aluminum is preferentially dissolved leaving a high alloy concentration on the metal surface resistant to attack.

3. After considerable reaction, a corrosion product layer forms which acts as a protective diffusion barrier.

TABLE III. *Effect of metal chlorides on corrosion of 99.99% aluminum in boiling, distilled* CCl_4

Solution	Weight loss (mg/cm^2/6 hr)	
	(A)	(B)
Distilled CCl_4	72.3	76.4
$AlCl_3$, saturated	101.4	97.6
$FeCl_3$, saturated	101.8	96.8
$CuCl_2$, saturated	77.3	72.3
$MnCl_2$, saturated	76.3	78.7

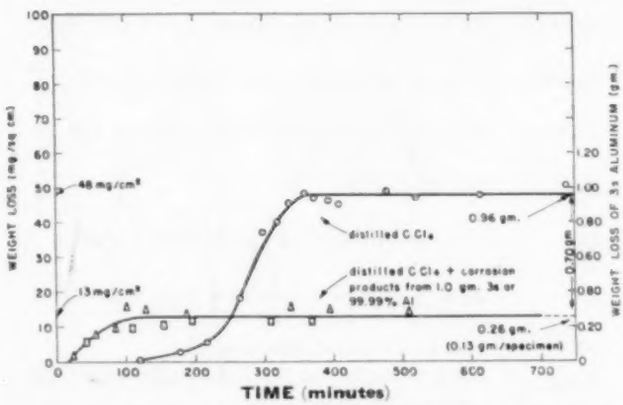

FIG. 2. Weight loss as a function of time for 3S (1.22% Mn) aluminum in boiling, distilled CCl_4 and in CCl_4 containing corrosion products from 1.0 gram of 3S or 99.99% aluminum. Two specimens, each 10.0 cm^2, immersed in 250 ml CCl_4.

If manganese corrosion products act as inhibitors for corrosion of 3S aluminum, then they may also inhibit reaction of high purity aluminum. To check this, one gram of 3S and one gram of 52S aluminum (2.43% Mg)—it will be shown later that magnesium alloys act similar to 3S—were reacted in CCl_4, and then weighed specimens of high purity aluminum immersed. The data contained in Table IV show that the weight loss is not lower but higher in these solutions than in distilled CCl_4. This is accounted for by a decrease of induction time due to presence of $AlCl_3$ in the corrosion products, as shown previously by data of Table II. Therefore, manganese and magnesium alloy corrosion products do not act as inhibitors for aluminum.

It was of interest next to determine whether cor-

rosion products affect the limiting weight loss for the 3S alloy. One gram of 3S aluminum was reacted in 250 ml of distilled CCl_4, followed by immersion of weighed 3S specimens in the solution. The procedure was repeated with initial reaction of one gram of 99.99 per cent Al. It was found (Table IV) that the limiting weight loss for 3S decreased from about 48 mg/cm² to approximately 13 mg/cm² in both solutions. Manganese corrosion products are not unique in this respect, since 99.99 per cent Al corrosion products were just as effective. This experiment proves that the marked decrease in corrosion rate (or the existence of a limiting weight loss) is not caused by concentrations of manganese salts in CCl_4, but rather by aluminum corrosion products. Manganese powder suspended in boiling CCl_4, for example, had no effect on the limiting weight loss of 3S alloy.

TABLE IV. *Effect of manganese corrosion products on corrosion of aluminum in boiling carbon tetrachloride*

Metal or Alloy	Solution 250 ml total volume	Weight loss (mg/cm²/6 hr) (A)	(B)	Comments
99.99%	Distilled CCl_4	74.0	71.1	Induction time equals approximately 70 min
99.99%	CCl_4 + corrosion products from 1 g 99.99% Al	92.2	97.1	Corrosion products of high purity Al decrease induction time
99.99%	CCl_4 + corrosion products from 1 g 3S	89.5	92.0	Effect similar to that of high purity Al products
99.99%	CCl_4 + corrosion products from 1 g 52S	99.5	101.6	Effect similar to that of high purity Al products
3S	Distilled CCl_4	46.2	48.4	Weight loss after which corrosion rate falls to a low value
3S	CCl_4 + corrosion products from 1 g 3S	12.6	13.4	3S products decrease weight loss after which corrosion rate falls to a low value
3S	CCl_4 + corrosion products from 1 g 99.99% Al	13.8	12.9	High purity Al products similar to 3S corrosion products
3S	Distilled CCl_4 + Mn powder	47.8	48.6	No effect
3S	Mn powder boiled for 17 hr in distilled CCl_4 before 3S introduced	43.5	46.2	No effect
3S	3S corroded to plateau (48 mg/cm²) and then immediately placed in fresh CCl_4	92.3	89.8	Corrosion products must be in solution for protective film to form

An additional experiment (Table IV) was conducted in which 3S specimens were reacted to the limiting weight loss in 250 ml CCl_4 (48 mg/cm²) and then immediately placed in a fresh solution without disturbing the specimen surface. The total weight loss was now about twice normal, or 91 mg/cm². This experiment proves that only corrosion products in solution are concerned with stifling of corrosion after a given time, and that the protective action is lost when a specimen previously exposed to CCl_4 is transferred to pure CCl_4.

Pursuing this matter further, specimens of 3S alloy were immersed in 250 ml CCl_4, containing corrosion products from one gram of 3S or 99.99 per cent Al, and the weight loss determined as a function of time (Fig. 2). As expected from previous data, the induction time is decreased, as well as the limiting weight loss. Instead of 48 mg/cm², the limiting weight loss becomes only 13 mg/cm².

All these investigations rule out the possibility of protective metal layers or intermetallic compounds at the alloy surface resulting from preferential corrosion of the aluminum component. They support instead the third possibility, namely, formation of a protective corrosion product layer.

Actually, the decrease in rate beyond the limiting weight loss is attended by a visible adherent reaction-product film. During the period of rapid attack, the appearance of 3S is similar to that of 99.99 per cent Al—a flocculent, porous, black, insoluble surface product forms. However, when the 3S alloy reaches the plateau of weight loss vs. time, this flocculent product (by analysis mostly $AlCl_3$) drops off and leaves a thin, adherent, brittle black film which is apparently quite protective. If the specimen is allowed to remain in the solution for several weeks rather than the usual time of less than one day, the film thickness increases to several tenths of a millimeter. Fig. 2 also shows that after 0.96 gram (48 mg/cm²) of 3S aluminum reacts in 250 ml of CCl_4 the corrosion rate levels off, but if corrosion products from one gram of 3S or 99.99 per cent Al are present, only 0.26 gram (13 mg/cm²) reacts before the plateau is reached.

Fig. 3 is a plot of the limiting weight loss of 3S as a function of the amount of 3S or 99.99 per cent aluminum previously reacted in 250 ml of CCl_4. The limiting weight loss is 48 mg/cm² when no aluminum has previously reacted with the CCl_4 and drops linearly to a constant value of 13 mg/cm²

for weights of aluminum previously reacted greater than 0.70 gram.

The information in Fig. 2 and 3 suggests that a minimum concentration of corrosion products must accumulate in solution in order to start film formation (first period), and an additional reaction of metal must occur to build a protective film (second period). Also, no matter how much aluminum has previously reacted with the solvent, new specimens lose a definite weight before the reaction rate plateau is achieved. This indicates that the volume of solu-

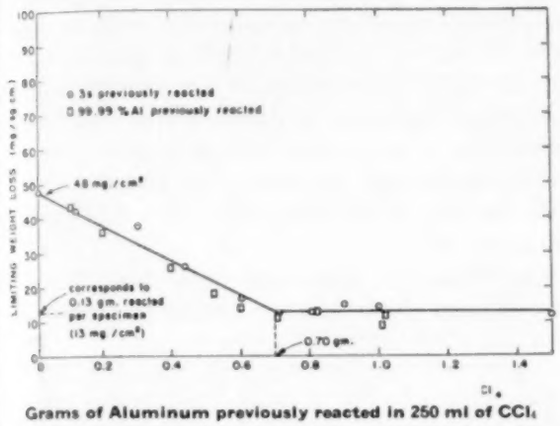
3s previously reacted
99.99 % Al previously reacted
48 mg/cm²
corresponds to 0.13 gm. reacted per specimen (13 mg/cm²)
0.70 gm.
LIMITING WEIGHT LOSS (mg/sq cm)
Grams of Aluminum previously reacted in 250 ml of CCl₄

FIG. 3. Limiting weight loss of 3S (1.22% Mn) aluminum as a function of the amount of 3S and 99.99% aluminum previously reacted in 250 ml of boiling, distilled CCl_4. Two specimens, each 10.0 cm², 6-hr exposure.

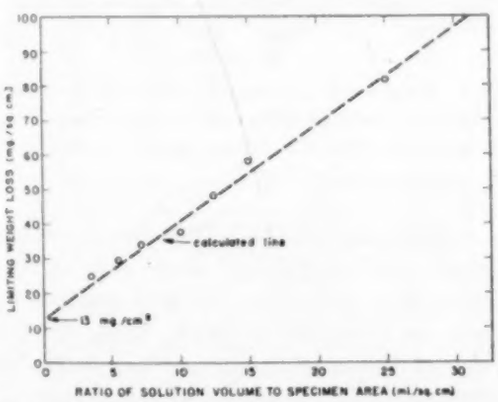

FIG. 4. Effect of the solution volume to specimen area ratio on the limiting weight loss of 3S (1.22% Mn) aluminum in boiling, distilled CCl_4; 8-hr exposure.

tion is critical in determining the first period weight loss. The quantitative data of Fig. 2 and 3 allow prediction of this effect by assuming that 0.70 gram of aluminum reacts in 250 ml of CCl_4 before film formation, and that 13 mg/cm² of aluminum react subsequently to build the film to a protective thickness. This leads to the following relation: $LWL = 2.8\ V/A + 13$, where: LWL = limiting weight loss, or weight loss/unit area at the plateau in mg/cm²; V = volume of CCl_4 in milliliters; and A = area of aluminum exposed in cm². Experimental data where the ratio of volume to area was varied from 3 to 25 check this equation, as illustrated in Fig. 4.

The above information shows that a plot of weight loss as a function of time for 3S aluminum in distilled carbon tetrachloride (shown in Fig. 2) is a special case, since the position of the plateau depends on the particular volume/area ratio chosen. Fig. 5 gives a more complete picture of the situation, showing the position of the plateau as observed for two volume/area ratios and as predicted from Fig. 4 for other ratios.

Corrosion in the vapor.—Reaction in the vapor is a condition similar to an experiment in liquid solution with a volume/area ratio of essentially zero. Weight loss tests of 3S aluminum specimens in CCl_4 vapor were carried out using the glass apparatus illustrated in Fig. 6 which was insulated with several layers of aluminum foil. A volume/area ratio of zero means that the metal area is so large

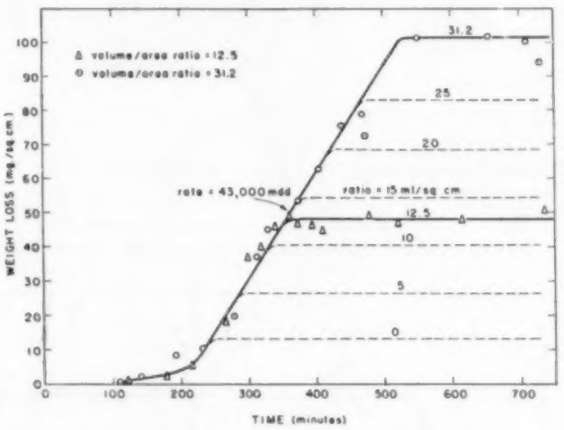

FIG. 5. Effect of various solution-volume to specimen-area ratios on the weight loss as a function of time for 3S (1.22% Mn) aluminum in boiling, distilled CCl_4.

that as soon as a small amount of attack occurs, the environment becomes sufficiently concentrated in corrosion products to cause immediate building of the protective film responsible for the plateau. Fig. 7 shows that 3S reaches such a plateau in the vapor phase for a weight loss of only 10 mg/cm². This is comparable with a weight loss of 13 mg/cm² for an extrapolated volume/area ratio of zero in the liquid phase (Fig. 4).

In one additional experiment, specimens were suspended below the liquid reflux trap, rather than from the glass hooks illustrated in Fig. 6, so that condensate flowed continuously over the specimens. This procedure is equivalent to operating a solution weight loss test in which the volume/area ratio is infinite. As expected, a two-gram specimen reacted to completion without the formation of a protective corrosion product film.

Corrosion of pure aluminum in CCl_4 vapor is not

unlike its behavior in boiling liquid CCl_4 (Fig. 8). The scatter of data is somewhat greater, but the average final corrosion rate is the same, and the induction period not far different.

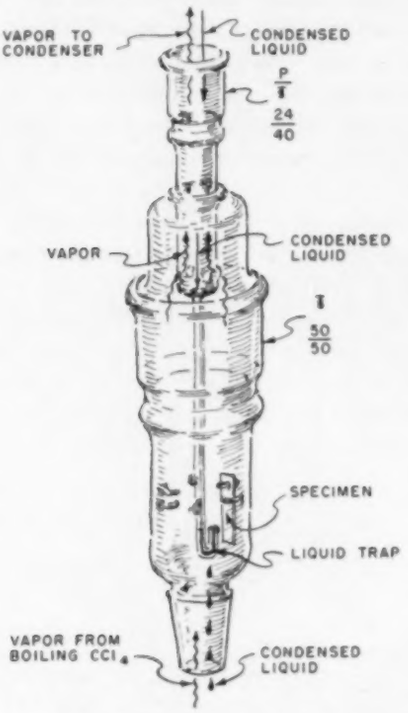

FIG. 6. Vapor phase corrosion testing apparatus

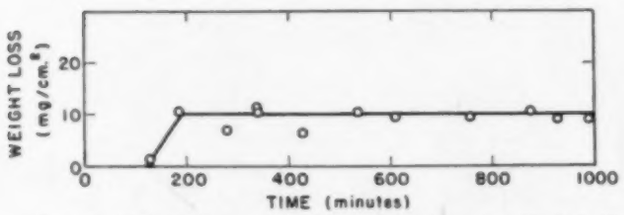

FIG. 7. Weight loss as a function of time for 3S (1.22% Mn) aluminum in the vapor of boiling, distilled CCl_4.

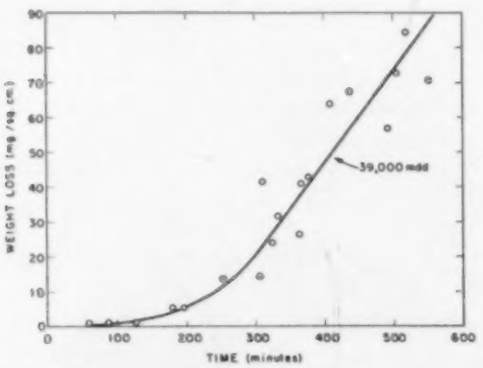

FIG. 8. Weight loss as a function of time for 99.99% aluminum in the vapor of boiling, distilled CCl_4.

Corrosion of magnesium-aluminum alloy.—It was found that the behavior of an aluminum alloy (B50S) containing 1.09 per cent Mg as major alloying constituent was similar to that of 3S, except for quantitative details. Fig. 9 contains weight loss information as a function of time for pure CCl_4 and for CCl_4 containing corrosion products. The equation describing the influence of the volume/area ratio on the limiting weight loss determined in the same manner as for 3S aluminum, was found to be:

$$LWL = 1.8\ V/A + 7.$$

Alloying constituents responsible for plateau.—In order to determine whether the major alloying constituent in 3S (1.22% Mn) and in B50S (1.09% Mg), or a minor constituent common to both, is responsible for the existence of a limiting weight loss, two special alloys were obtained by courtesy of the Aluminum Company of America Research Laboratories. One was an alloy of high purity aluminum with 1.30 per cent Mn (alloy N), and the other an alloy of high purity aluminum with 1.01 per cent Mg (alloy G).

Fig. 10 and 11 show that both these alloys display plateau characteristics similar to their respec-

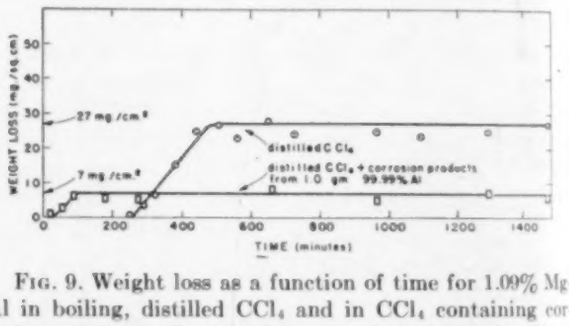

FIG. 9. Weight loss as a function of time for 1.09% Mg-Al in boiling, distilled CCl_4 and in CCl_4 containing corrosion products. Two specimens, each 11.3 cm², in 250 ml CCl_4.

tive commercial alloys. Therefore, presumably manganese and magnesium alone can be effective in producing a protective reaction product film.

It will be observed, however, that quantitative behavior of the special alloys differs from that of the corresponding commercial alloys, despite a close similarity in composition regarding the major alloy additions. The pure manganese alloy corrodes at about the same rate as the commercial alloy and has a similar induction period, but it reaches the plateau only after considerably more of the alloy has corroded. The pure magnesium alloy, on the other hand, has a shorter induction time compared with the commercial magnesium alloy and reaches the plateau after less alloy has corroded.

The limiting weight loss for these alloys can be expressed by the following equations:

Alloy N, 1.30% Mn: $LWL = 4.6V/A + 18$

Alloy G, 1.01% Mg: $LWL = 1.4V/A + 3.$

Properties and characteristics of protective reaction product film.—It was of interest to determine next whether the plateau in the weight loss-time curve of the various alloys corresponds to a zero corrosion rate, or whether it really has a finite slope. Alloy G (1.01% Mg) provided values of weight loss at the plateau which checked within 1 mg/cm² when reacted in CCl_4 containing corrosion products from 2 grams of aluminum. By and large, this constituted better reproducibility than was obtained for the other alloys. Specimens of alloy G, therefore, were immersed for periods of time as long as 15 days instead of the usual time of less than one day. In addition to determining the weight loss of the specimens as a function of time, the weight and thickness of the protective reaction product were also recorded. Since the protective film is brittle, the film could be detached by pressing the edge of a razor blade against it, causing large flakes to chip off. A dial gage calibrated to 0.0001 in. was used to measure the depth of the step so produced.

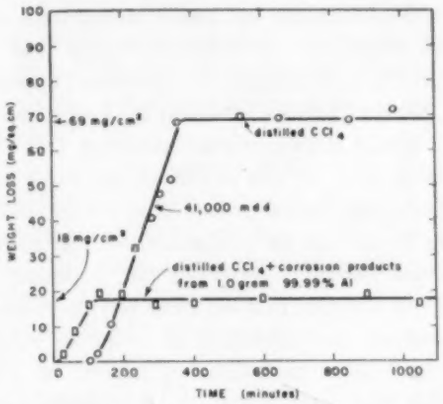

FIG. 10. Weight loss as a function of time for 1.30% Mn-Al in boiling, distilled CCl_4 and in CCl_4 containing corrosion products. Two specimens, each 11.4 cm², in 250 ml CCl_4.

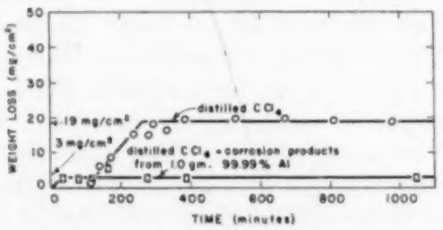

FIG. 11. Weight loss as a function of time for 1.01% Mg-Al in boiling, distilled CCl_4 and in CCl_4 containing corrosion products. Two specimens, each 11.4 cm², in 250 ml CCl_4.

Fig. 12 shows that alloy G reacts at a rate of 80 mdd when protected by the reaction product film, as compared to a value of about 40,000 mdd without such protection. The film thickness increases at a rate of 0.001 in. per day. Also, the film density, calculated from film weight as a function of film thickness, was found to average 2.28 gm/cm³ (Fig. 13). This value is to be compared with 2.46, the density of $AlCl_3$ reported by Hulsmann and Biltz (3).

Chemical analyses were made of the protective film formed on 3S(1.22% Mn) and on alloy G (1.01% Mg) by reacting the product in distilled water, filtering out the insoluble organic product, and analyzing the solution for aluminum, chlorides, and either manganese or magnesium. Six separate analyses, two conducted on films taken from 3S and four from alloy G, showed that the chlorine to aluminum atom ratio in the water-soluble portion of the films averaged 2.84 ± 0.04. The percentages of Mn and Mg in the film were 0.09 per cent and 0.15 per cent, respectively. The quantity of these elements in the films is of the same order, therefore, as corresponds to Mn and Mg originally present in the alloy. The weight per cent of water-insoluble organic product was 6.0 ± 0.5. Finally, the water-soluble organic products were negligible. These analyses provide no certain formula for the protective film, but indicate it to be either aluminum chloride with smaller amounts of complexed lower halides of aluminum, or an organic complex of aluminum chloride with chlorinated hydrocarbons.

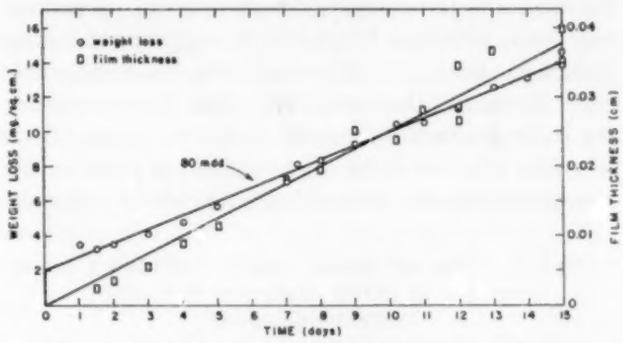

FIG. 12. Weight loss and film thickness as a function of time for 1.01% Mg-Al in boiling CCl_4 containing corrosion products from 2.0 grams of 99.99% aluminum.

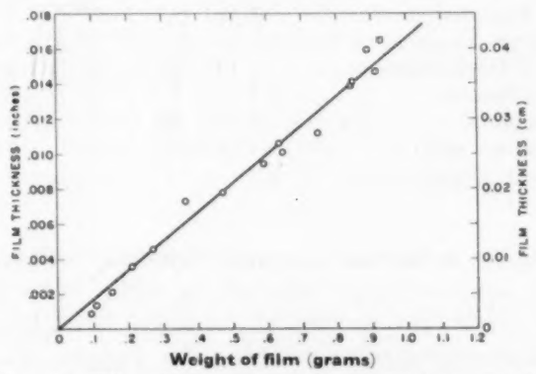

FIG. 13. Film thickness as a function of the weight of film formed on 1.01% Mg-Al in boiling CCl_4 containing corrosion products from 2.0 grams of 99.99% aluminum (film area 10.6 ± 0.2 cm²).

Discussion of Results

Review of the data for reaction of aluminum with carbon tetrachloride, reported in this paper and previously, shows that the mechanism of the reaction is not electrochemical. Instead, the reaction appears to be chemical in a straightforward sense of the term. The bulk of evidence focuses on a mechanism which depends on a sequence of free radical reactions. Such evidence comes from orange-red soluble reaction products, since color is characteristic of free radicals. Also, oxygen and water prolong the induction time, which they can presumably do by reaction with free radical species responsible for initiating the reaction. Many free radical organic reactions, inhibited by traces of oxygen, exhibit an induction time (4). The induction time in these cases is usually dependent upon the time necessary for boiling action to remove dissolved oxygen from solvents, whereas cause of the induction time for the aluminum-carbon tetrachloride reaction appears to reside in the natural protective oxide on aluminum, or, more specifically, relates to the water and perhaps oxygen content of the oxide. Accordingly, heat-treatment of aluminum under vacuum, which partially removes water and gases from the oxide, successfully reduces the induction time.

TABLE V. *Effect of various organic compounds on the reaction of 99.99% aluminum in boiling carbon tetrachloride*

Addition agent	Amount added	Time (hr)	Weight loss (mg/cm²)
Nothing added	—	12	113.2
1,4-Naphthoquinone	0.4 (wt. %)	72	0.0
Quinone	0.4 (wt. %)	24	0.6
1,3,5-Trinitrobenzene	0.4 (wt. %)	24	0.1
Nitrobenzene	0.4 (vol. %)	24	0.9
Acetone	0.2 (vol. %)	12	0.0
Ethyl acetate	0.4 (vol. %)	12	0.0
3-Methoxypropylamine	0.4 (vol. %)	12	0.0

Aluminum chloride added to carbon tetrachloride decreases the induction time presumably by providing a source of free radicals either through itself dissociating into lower chlorides, or by forming complexes with CCl_4. Alloying constituents can similarly suppress the reaction by preferentially reacting with free radical species responsible for starting the reaction. This explains the pronounced reluctance of Mg-Al alloys to react (long induction time) and their lack of response to vacuum treatment.

Finally, substances capable of suppressing free radical formation act as inhibitors. Since chain reactions can be propagated only so long as all the intermediate reactions occur, it follows that various suppressors at low concentrations can effectively slow down participating reactions involving free radical species. Thus, many foreign substances, including small amounts of water and oxygen, retard reactions which proceed by a free radical chain mechanism (5–8). Included in these are a variety of organic compounds.

In this connection, several organic compounds, many of them recognized free radical suppressors (5–8), were added to carbon tetrachloride in order to determine their effect on corrosion of pure aluminum. Results are summarized in Table V, confirming that these compounds are successful corrosion inhibitors. Since many of these substances are not corrosion inhibitors in aqueous media and, hence, are not likely to function by adsorption on the metal surface, their plausible function is to suppress one or more of the chain reactions involving free radicals. These facts add to the evidence outlined above.

Further tests demonstrated that compounds listed in Table V can act as inhibitors even after reaction has started, further verifying the proposed mechanism. Pure aluminum specimens were scraped under boiling carbon tetrachloride in order to initiate reaction, and then immediately placed in solutions containing the compounds. All compounds were effective in decreasing the weight loss corresponding to a 12-hr test period.

Since active free radicals are not apt to be specific in their reactions, this explains why processes depending on free radicals are easily inhibited, and also why they undergo numerous side reactions producing a variety of reaction products. For example, in the course of examining the protective film on 3S and corrosion products from pure aluminum, small amounts of gas were liberated when the products were hydrolyzed in water. With the aid of mass spectrometer analysis, through courtesy of the M. W. Kellogg Company, gas so liberated from corrosion products of pure aluminum was found to be largely methane. The methane may come from small amounts of aluminum carbide produced by side reactions or perhaps by hydrolysis of aluminum chloride complexes.

Proposed Free Radical Sequence for the Al-CCl_4 *Reaction*

A consideration of the facts relating to the present reaction, and to previously studied organic reactions, suggests the following chain sequence as a plausible mechanism for the Al-CCl_4 reaction:

$$\left.\begin{array}{ll} (A)\ CCl_4 \rightarrow {}^{\cdot}CCl_3 + {}^{\cdot}Cl \\ (B)\ Al + {}^{\cdot}Cl \rightarrow AlCl \end{array}\right\} \quad \text{Initiation}$$

$$(C)\ AlCl + CCl_4 \rightarrow AlCl_2 + {}^{\cdot}CCl_3$$

$$(D)\ AlCl_2 + CCl_4 \rightarrow AlCl_3 + {}^{\cdot}CCl_3$$

$$(E)\ AlCl_3 + CCl_4 \rightarrow CCl_3^{+}[AlCl_4]^{-}$$

$$(F)\ CCl_3^{+}[AlCl_4]^{-} \rightarrow AlCl_3 + {}^{\cdot}CCl_3 + {}^{\cdot}Cl$$

} Propagation

$$(G)\ 2\,{}^{\cdot}CCl_3 \rightarrow C_2Cl_6$$

$$(H)\ {}^{\cdot}Cl + {}^{\cdot}CCl_3 \rightarrow CCl_4$$

} Termination

The above reactions are equivalent to the major over-all reaction already described: $2Al + 6CCl_4 \rightarrow 2AlCl_3 + 3C_2Cl_6$. The reactions and the free radicals described above are common to mechanisms of organic chemistry (9–13), particularly in a solvent such as carbon tetrachloride which has a low dielectric constant.

Accordingly, it is concluded that the Al-CCl_4 reaction is initiated by the formation of active particles (free radicals or atoms), the formation of which accelerates with time until their rate of generation equals their rate of destruction. When this steady state is reached, the reaction velocity becomes constant and independent of the bulk concentrations of the main reactants. This explains the constant corrosion rate found for high purity aluminum in carbon tetrachloride, as well as a similar corrosion rate for aluminum in the vapor (Fig. 8). In the vapor phase, the steady-state concentration of active free radicals at the surface is conceivably the same as that found in the liquid, since the concentration may depend upon rate of decomposition of a complex formed on the surface [reaction (*F*)]. Neither corrosion products nor aluminum chloride influence the reaction rate (contrary to their effect on the induction period), since CCl_4 is already saturated with $AlCl_3$ soon after the reaction begins. Thus, addition of aluminum chloride is not expected to increase the concentration of complex shown in reaction (*E*).

The fact that hydrogen chloride increases the reaction rate after the induction period can be explained by the following chain sequence, in accord with similar reactions studied under conditions of low pressure gas discharge (14, 15).

$$(J)\ Al + HCl \rightarrow AlCl + {}^{\cdot}H$$

$$(K)\ {}^{\cdot}H + CCl_4 \rightarrow {}^{\cdot}CCl_3 + HCl$$

AlCl and ${}^{\cdot}CCl_3$ then follow reactions (*C*) through (*H*). Reactions (*J*) and (*K*) also explain why water increases the corrosion rate, since water hydrolyzes aluminum chloride, thereby producing HCl. This mechanism shows why the total reaction is increased by water more than can be accounted for by hydrolysis of CCl_4:

$$CCl_4 + 2H_2O \rightarrow CO_2 + 4HCl$$

$$4HCl + \tfrac{4}{3}Al \rightarrow \tfrac{4}{3}AlCl_3 + 2H_2$$

since water and HCl are used up in this process and the sustained ability of a small amount of water to increase the rate is not accounted for. The free radical mechanism, on the other hand, provides for production of HCl which is not consumed and, hence, better explains the observations.

Reactions (*E*) and (*F*) reasonably explain the decrease in induction time caused by corrosion products and by aluminum chloride. Part of the experimental evidence for these reactions comes from the fact that aluminum chloride has been found to exchange chlorine atoms with carbon tetrachloride (16, 17). The corrosion product hexachlorethane forms logically from the combination of two ${}^{\cdot}CCl_3$ radicals.

By and large, therefore, the various properties and products of the CCl_4-Al reaction are satisfactorily accounted for by a free radical mechanism.

Acknowledgment

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Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the Journal.

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The Interaction of Organic Compounds with the Surface during the Electrodeposition of Nickel[1]

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ABSTRACT

Measurements of the cathode potential were made during electrodeposition of nickel in the presence of 76 organic compounds. The ability of the compound to make the cathode potential more negative at a fixed current density was dependent upon: (*a*) the acidic or basic character of the compound; (*b*) the size of the molecule; and (*c*) the number of available pairs of electrons in the molecule. Available pairs of electrons are defined as those which are capable of being shared with other atoms through association or chemical reaction without breaking completely the original bond between the atoms involved. Cathode polarization was appreciably increased by low concentrations of basic compounds with a large number of available pairs of electrons and/or with a large molecular size. The comparative effectiveness of chemical groups in increasing polarization decreased in the following order: nitrogen in conjugated bicyclic ring, nitrogen in conjugated monocyclic ring, nitrile, aldehyde, amino, nitro, tertiary amine, sulfone, sulfonylamide, sulfonate, carboxyl, ketone, and phenolic or alcoholic hydroxy. Simultaneous measurements of cathode potential and brightness of the surface indicated that the largest compounds required the smallest concentration to brighten the surface, and the smallest compounds required the largest concentration. Brightening first occurred in the majority of instances at a cathode potential 20–50 mv more negative than that of an unadulterated bath. The conclusion was drawn that the lowest concentration required for brightening corresponded to a specific fractional coverage of the surface. Brittleness, peeling, and cracking of the deposit were correlated with high polarizations. The origin of the change of the cathode potential in the presence of organic compounds was attributed to interference at the cathode surface with some stage in the over-all process, $Ni^{++} + 2e \rightarrow Ni(cryst.)$. Adsorption experiments with Raney nickel and measurements of the electrode potential in 1*N* hydrochloric acid indicated that the compounds most effective in increasing the cathode potential were readily adsorbed by nickel. The experiments in hydrochloric acid also indicated that the adsorbed compounds interfered with the electron transfer, and x-ray measurements reported in another paper indicated that the compounds interfered with crystal growth.

INTRODUCTION

Organic compounds in small concentrations are added to metal plating baths for a variety of purposes. In the case of nickel, additions are made to reduce pitting, to increase hardness, to remove strains in the deposit, to fill in macroscopic scratches, and to impart a mirror-like luster to the surface. The excellent baths which are available commercially for these purposes have been developed by a process akin to an art rather than a science. With the exception of the antipitting or wetting agents, there appears to be very little scientific understanding of the interaction of organic compounds with a metal surface during electroplating. As a start toward a better understanding, cathode potential measurements have been undertaken with the purpose of gaining an insight into the behavior of organic compounds at the surface during the actual plating process.

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EXPERIMENTAL

Cathode potential experiments.—Cathode potentials were determined by pressing a capillary tip against the cathode and measuring the total potential of the cell, consisting of the nickel cathode, nickel plating solution, and a saturated KCl calomel half-cell. Two capillary tips were used in all experiments, and the electrical circuit was such that potential readings could be made on both tips during an experiment. In the great majority of experiments, the results with both tips were similar. If any discrepancy was observed, the experiment was discontinued and the tips were relocated on the surface.

A copper sphere, $\frac{5}{8}$ in. in diameter, with a small supporting shaft served as the cathode. The spherical shape was chosen because it was felt that the cur-

rent density would be essentially uniform over the entire surface. In verification of this assumption it was visually noted at low current densities that a copper sphere was uniformly coated with nickel. The supporting shaft was electrically insulated from the solution by means of a plastic holder. Electrical connections were made through a rod screwed into a threaded hole in the shaft of the sphere. In order to avoid effects resulting from possible anodic oxidation of the organic additives, the anode was maintained in a separate vessel, which was connected to the cathode compartment by means of a bridge filled with nickel plating solution.

The solution used in these experiments and commonly referred to as the Watts bath had the following composition: $NiSO_4 \cdot 6H_2O$ 240 g/l, $NiCl_2 \cdot 6H_2O$ 45 g/l, and H_3BO_3 30 g/l. After dissolving the constituents, the *p*H of the solution was raised with $NiCO_3$. The solution was then filtered, and the *p*H was lowered to 4.0 with HCl. Organic compounds were added in increasing amounts to the solution in the cathode compartment during the course of a run, either in weighed amounts or as a concentrated solution adjusted to *p*H 4.0. The *p*H was adjusted to 4 after every addition, when necessary. Between 5 and 15 different concentrations were used with each compound.

The cathode was mechanically polished through 4/0 emery paper prior to each run, and was then preplated with nickel in the absence of addition agent for 10 min at 2 amp/dm^2. The following standard experimental conditions were used in the potential studies: agitation of bath—none; temperature—30°C; current density—1 amp/dm^2; and *p*H—4.0. A few experiments were also carried out at 50°C and a current density of 2.0 amp/dm^2.

Cathode potential studies at low current densities.—Measurements of the cathode potential were also made at low current densities of the order of 10^{-2} amp/dm^2 and at potentials at which nickel first begins to deposit at an appreciable rate. The cathode potential and the current flowing through the cell were determined as the potential applied to the cell was increased at a fixed rate. The method was similar in essentials to that used in polarography. The cathode potential was determined by means of a compact capillary tip and calomel electrode assembly inserted in the plating solution. The current flowing through the cell was measured with the aid of a galvanometer and Ayrton shunt, and the voltage supplied to the plating cell was controlled by a system of rheostats which permitted varying the potential range being studied. The slider of one of these rheostats was connected to a threaded shaft, and the shaft was driven by means of a motor and a system of reduction gears so that the cell potential could be increased at a fixed rate. In the case where the current remained essentially constant over a wide range of applied potentials, the rate of increase of the cathode potential was maintained at 5 mv/min. When the current flowing through the cell changed with the applied potential, the rate of increase of the cathode potential automatically decreased greatly. The cathode potential and the current flowing through the cell were measured every 30 sec during the course of an experiment, which generally lasted 40 min.

The same Watts plating bath was used in these studies, and all experiments were carried out at 30°C, a *p*H of 4.0, and in the absence of agitation. The surface condition of the cathode was found to play a major role in the results. In order to secure a reproducible surface in each run, the spherical copper cathode was electrolytically polished in phosphoric acid, and was placed in the plating bath immediately after removal from the polishing solution and thorough washing in a stream of tap water.

Potential measurements in N HCl.—The electrode potential of a nickel cylinder was determined in normal HCl as increasing amounts of organic material were added to the acid. All experiments were carried out in a thermostat at 30°C, and the total potential of the cell, consisting of a saturated KCl calomel half-cell and the nickel-acid half-cell, was measured. No capillary tip was required in these experiments since no current was flowing.

The nickel cylinder was surfaced in the following manner before each experiment. The cylinder, 15 mm in diameter and 15 mm long, was held by means of an attached shaft in a plastic holder. The use of a plastic holder made it unnecessary to touch the nickel surface during preparation. The holder was clamped in a chuck attached to an electric motor and the nickel was polished to a high luster by pressing 3/0 and 4/0 emery paper against the specimen while it rotated. Clinging fragments of emery and abraded nickel were removed from the surface with a clean paper tissue. The cylinder was inserted in the acid immediately after mechanical polishing. Electrical connections were made through a screw threaded through the plastic holder and into the nickel specimen.

Adsorption of organic compounds by Raney nickel.—Finely divided nickel-aluminum alloy (Raney nickel catalyst powder) was obtained from the Central Scientific Company and was treated to form Raney nickel, according to the directions furnished by the supplier. The aluminum was leached out with NaOH, and the nickel powder was washed free of alkali by repeated additions of water and decantations until the *p*H fell to 7.

TABLE I. *Classification of 76 organic addition agents according to their increasing effects on the cathode potential during the electrodeposition of nickel*

Division 1	
Acetylacetone	Ethanolamine
o-Aminophenol	Methylamine
m-Benzenedisulfonic acid (Ni salt)	Naphthalene 1, 3, 6 trisulfonate (Na salt)
Benezenesulfonic acid	Phenol
Benzoic acid	*p*-Phenolsulfonic acid
Sec.-butylamine	Piperidine
Cyclohexylamine	Quinone
Diethylamine	Taurine
Diethylaniline	*p*-Toluenesulfonic acid
Ethanol	Triethylamine
Ethylamine	

Division 2	
Benzylamine	Naphthalene 1,5 disulfonate (Na salt)
N, N di (beta-hydroxyethyl) aniline	2-Naphthylamine 5,7 disulfonic acid
Dihydrothianaphthene dioxide	1-Naphthylamine 4,8 disulfonic acid (Na salt)
Dodecylamine	Orthanilic acid
N ethyl *N* beta-hydroxyethyl aniline	Saccharin
Ethylenediamine	Sulfamic acid
Furfural	Sulfanilic acid
p-Hydroxybenzonitrile	*m*-Sulfobenzaldehyde (Ni salt)
Lactonitrile	*m*-Sulfonitrobenzene
Naphthalene 2,7 disulfonate (Na salt)	Thianaphthene dioxide
	p-Toluene sulfonylamide

Division 3	
Acrylonitrile	Benzaldehyde
m-Aminophenol	Propionitrile
p-Aminophenol	Thiourea

Division 4	
p-Aminobenzonitrile	Ethylenecyanohydrin
Aniline	Glycolonitrile
Diethylenetriamine	Gamma-hydroxybutyronitrile
Sym.-diethylthiourea	Nitrobenzene

Division 5	
Benzonitrile	Alpha-picoline
Coumarin	Pyridine
2,4,6 Collidine	Quinoline
m-Phenylenediamine	Succinonitrile
p-Phenylenediamine	

Division 6	
N-methyl isoquinolinium methylsulfate	Quinaldine
o-Phenylenediamine	Tetraethylenepentamine

Division 7	
Isoquinoline	Quinaldine ethiodide
Melamine	Quinoline ethiodide

Division 8	
Magenta dye	Polyamine 1200
Polyamine 650	

Since the nickel powder was pyrophoric, it was impossible to dry and weigh the powder used in the adsorption studies. In order to circumvent this difficulty, the amount of nickel used in each experiment was measured in terms of volume. Spoonfuls of an aqueous nickel powder slurry were washed into a graduate cylinder, and the powder was allowed to settle. Approximately 15–20 min were required for the powder to settle to a volume which changed very slowly with time. In general, 20 ml settled volume of powder was used for each determination. In a few cases, smaller volumes were used. As outlined later, the adsorption activity of this nickel powder was not similar in different preparations, and decreased with time of storage.

The organic material was added to the nickel powder-water mixture in the form of a concentrated solution of known normality, and the total volume was adjusted to 100 ml. The reaction flask was stoppered, placed in a thermostat at 30°C, and the mixture was agitated frequently during the first 2 hours. The nickel powder was allowed to settle overnight and, in the morning, 25 ml of the clear solution was pipetted from the flask and titrated with 0.1*N* HCl. The *p*H of the solution was measured with a *p*H meter during titration, and the end point was determined from a plot of *p*H vs. ml of acid added. Even though the alkalies used for adsorption were weak, it was possible to obtain satisfactory end points.

Results

Cathode potential experiments.—Cathode potential measurements were made in the presence of 76 different organic agents. A list of these compounds is given in Table I, and the approximate effect of each compound can be judged from the table and the summary in Fig. 1. Representative data are also plotted in Fig. 2–10 for 23 of the compounds used in this study. The plots are presented as the increase in cathode potential[2] in mv caused by the

[2] The term "increase in potential" used throughout the paper in the discussion of the cathode potential experiments and in the captions of the figures indicates an increase in the cathodic polarization. The "increase" in potential in all cases is actually in the negative, or more cathodic, direction.

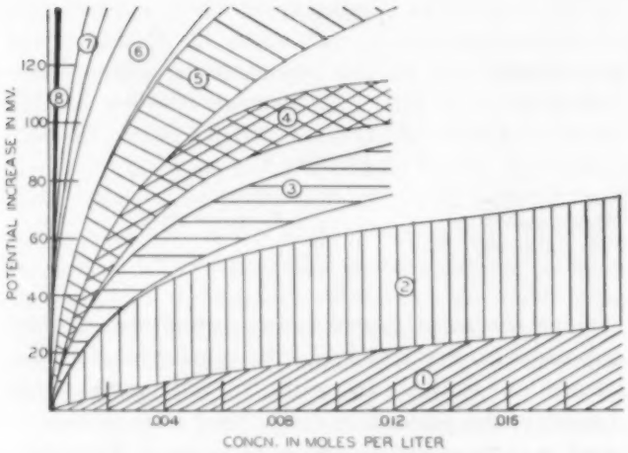


FIG. 1. Grouping of the 76 compounds according to their effect on the cathode potential (see Table I).

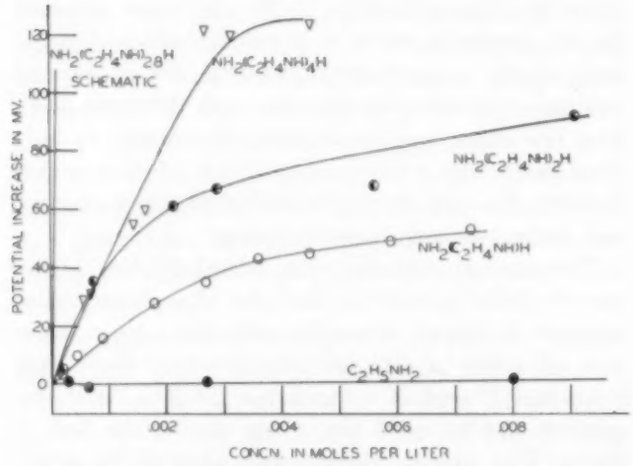


FIG. 2. Data showing the relation between the effect on the cathode potential and the number of amine groups in the molecule.

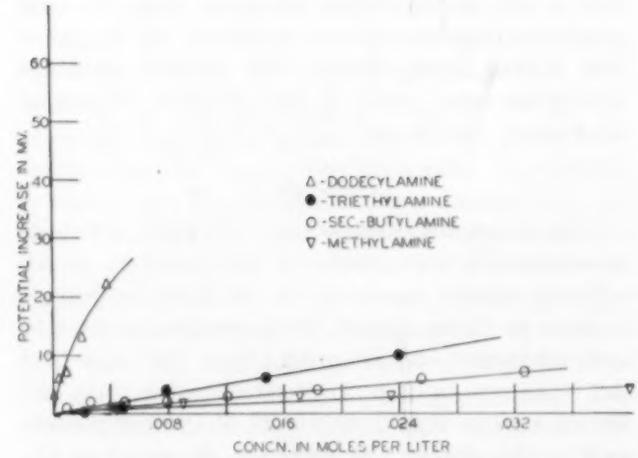


FIG. 3. Data showing the effect of molecular size in the cathode potential measurements with a group of alkyl amines.

addition agent vs. the concentration of the agent in moles/l. The increase in potential is the difference between the cathode potentials in the presence and absence of the organic compound.

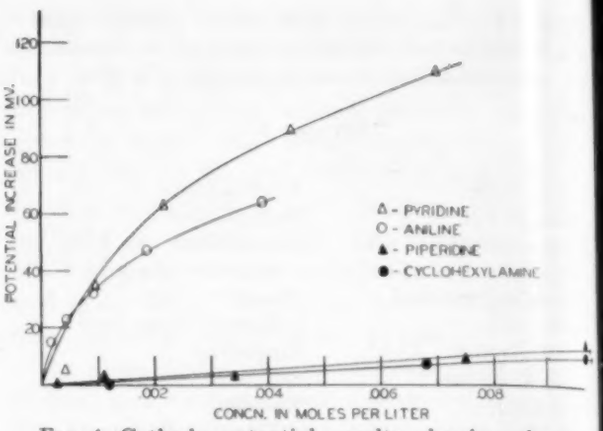


FIG. 4. Cathode potential results showing the great difference between the effects of saturated and unsaturated compounds of similar size.

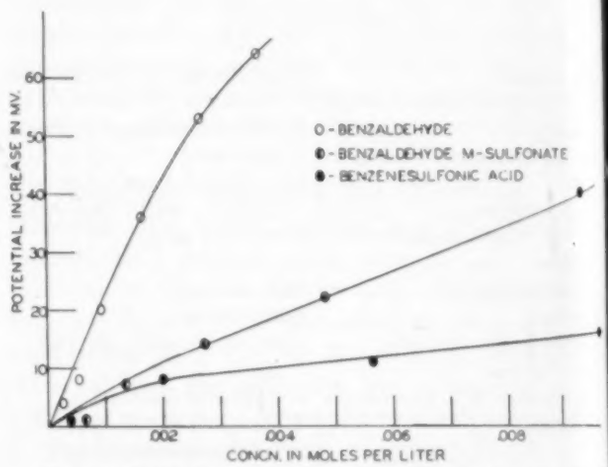


FIG. 5. Cathode potential results showing that the effect of acidic and basic groups meta to each other is intermediate to the effect of either group alone.

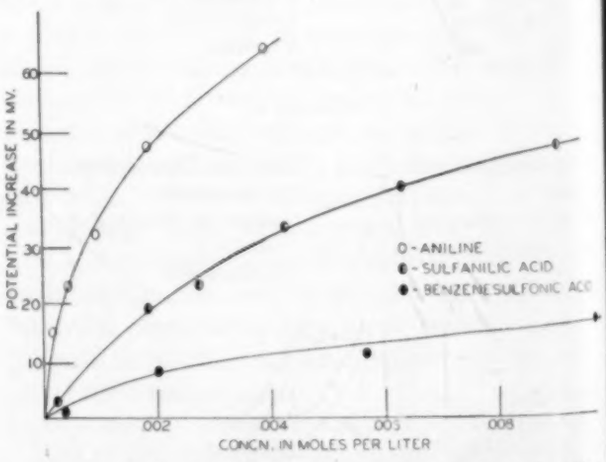


FIG. 6. Cathode potential results showing that the effect of neutral and basic groups para to each other is intermediate to the effect of either group alone.

In many cases, additional measurements of the cathode potential were made while the solution was agitated. In all cases, agitation had exactly the same effect as an increase in concentration of the organic compound. In the unadulterated bath and

in solutions containing compounds which had a negligible effect on the cathode potential in an unstirred solution, the cathode potential did not change upon agitation. In the case of compounds which increased the cathode potential in an unstirred solution, the increase in potential was dependent on the rate of stirring; the greater the rate of stirring, the greater the increase of the cathode potential.

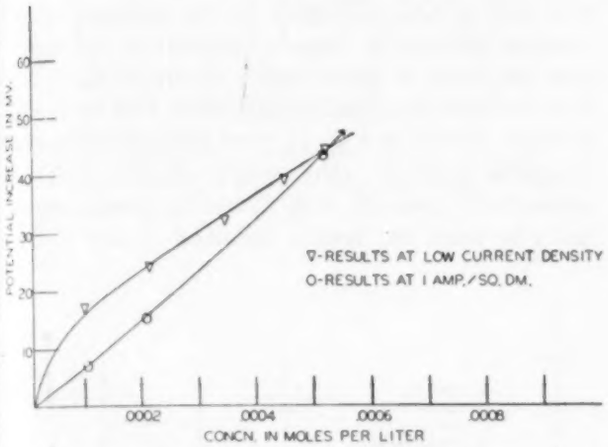


FIG. 7. A comparison of the cathode potential results with quinaldine ethiodide at low current densities and 1 amp/dm².

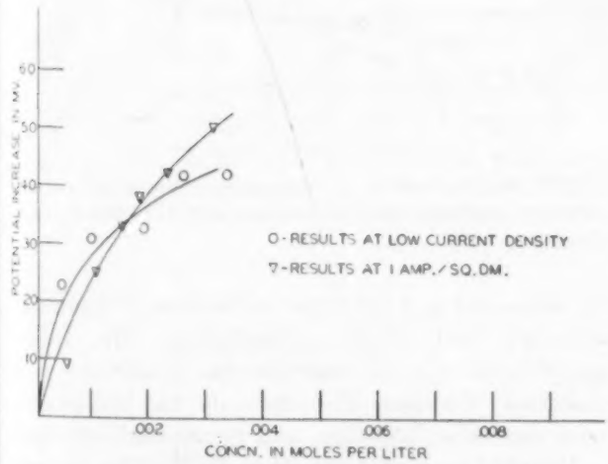


FIG. 8. A comparison of the cathode potential results with ethylenecyanohydrin at low current densities and 1 amp/dm².

During the course of an experiment, the nickel deposit was examined frequently with the aid of a flashlight without breaking the circuit or removing the cathode from the bath. Many of the compounds had the ability to impart luster to the deposit. A list of these is given in Table II, along with data on the lowest concentration at which brightening was noted and the potential increase in mv at which brightening was first observed. In almost all cases, the deposit became very brittle and tended to peel and crack from the spherical surface when the cathode potential increase was greater than 50 mv. Although no quantitative measurements were made, there appeared to be a direct relationship between the brittleness of the deposit and the increase in the cathode potential.

Cathode potential measurements were also carried out at 50°C and 2 amp/dm² in the case of cyclohexylamine, ethylenecyanohydrin, naphthalene 1,3,6 trisulfonate, Polyamine 1200 (polyethyleneamine with a molecular weight of 1200), pyridine, and

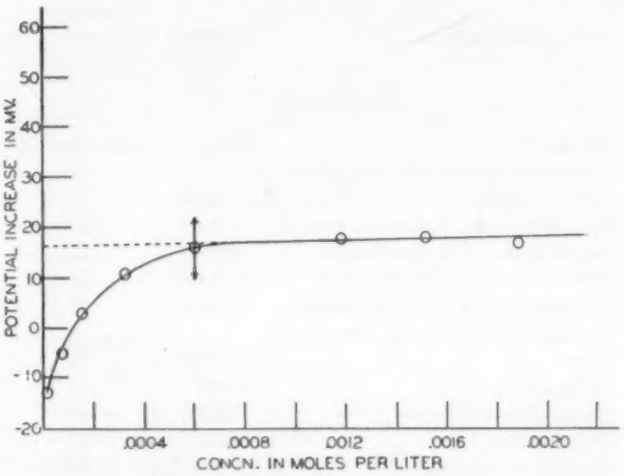


FIG. 9. Cathode potential-concentration curve for 1 naphthylamine 4,8 disulfonic acid. The first sign of brightening of the deposit is indicated by an arrow.

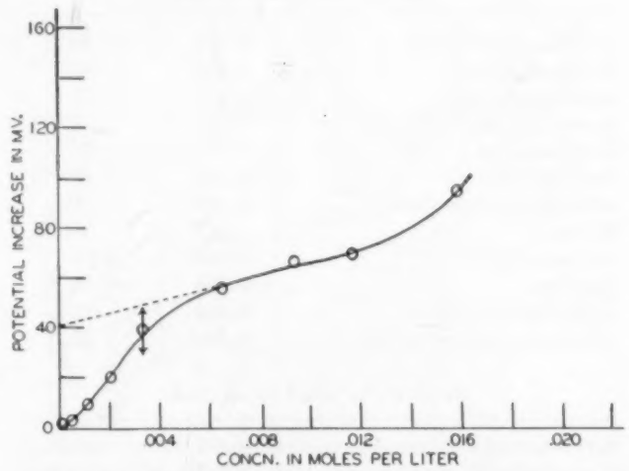


FIG. 10. Cathode potential-concentration curve for lactonitrile. The first sign of brightening of the deposit is indicated by an arrow.

quinaldine. The results under both sets of experimental conditions were qualitatively the same.

Cathode potential studies at low current densities.—These experiments were carried out to determine the importance of ohmic resistance in explaining the cathode potential results at current densities of 1 amp/dm². Currents of the order of 10^{-3} amp were used, and the contribution of an IR voltage to the measured potential was assumed to be negligible. These studies have been greatly extended,

TABLE II. *Tabular summary of the compounds which caused appreciable brightening of the nickel surface during deposition at 1 amp/dm², a* pH *of 4.0, and a temperature of 30°C*

Compound	Lowest concentration at which brightening was noted	Potential increase in mv for first sign of brightening
Very large compounds		
Magenta dye	0.0001 mole/-l	unknown-soln. opaque
Polyamine 1200	0.000015	23 mv
Bicyclic compounds		
Isoquinoline	0.001	less than 71
N-methyl isoquinolinium methylsulfate	0.0003	31
Naphthalene 1,5 disulfonate	0.0002	19
Naphthalene 2,5 disulfonate	0.0014	27
Naphthalene 2,7 disulfonate	0.0008	35
Naphthalene 1,3,6 trisulfonate	0.0006	27
l-Naphthylamine 4,8 disulfonic acid	0.0006	16
Quinaldine	0.001	42
Quinaldine ethiodide	0.0005	46
Quinoline	0.003	57
Quinoline ethiodide	0.001	36
Saccharin	0.0006	34
Thianaphthene dioxide	0.0001	28
Monocyclic compounds		
p-Aminobenzonitrile	0.002	26
m-Aminophenol	0.004	48
p-Aminophenol	0.001	22
m-Benzenedisulfonic acid	0.03	14
Benzenesulfonic acid	0.02	29
Benzonitrile	0.006	97
p-Hydroxybenzonitrile	0.008	27
Furfural	0.007	38
Alpha-picoline	0.008	ca 73
Pyridine	0.004	ca 88
m-Sulfobenzaldehyde	0.005	22
p-Toluene sulfonylamide	0.0015	28
Short chain alkyl compounds		
Acrylonitrile	0.003	30
Sym.-diethylthiourea	0.002	54
Ethylenecyanohydrin	0.002	39
Glycolonitrile	0.004	50
Gamma-hydroxybutyronitrile	0.005	43
Lactonitrile	0.005	38
Propionitrile	0.003	45
Succinonitrile	0.002	40
Miscellaneous compounds		
Tetraethylenepentamine	0.0006	51

but only results pertinent to the subject of this paper are included herein.

In the absence of organic compounds in the bath the current-potential curve took the form of curve *A* of Fig. 11. The current passing through the cell remained essentially constant until, at a potential of approximately 0.70 volt vs. the saturated KCl calomel half-cell, the current slowly increased. At precisely 0.717 volt, the current increased sharply, and the potential remained constant. Examination of the spherical copper cathode indicated that nickel first began to plate at an appreciable rate at this potential. In the presence of increasing amounts of organic compounds, the curves took the form of those shown in curves *B*, *C*, and *D* in the case of quinaldine ethiodide. Curves similar to those shown in Fig. 11 were obtained also with coumarin, pyridine, ethylenecyanohydrin and benzenesulfonic acid. In Fig. 7 and 8, comparison is made between the results obtained at low current

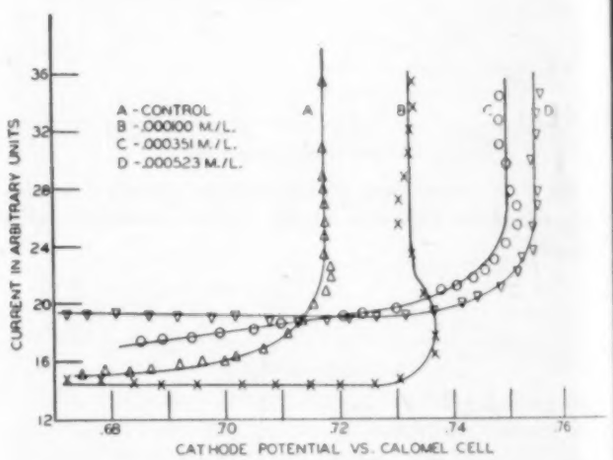


FIG. 11. The effect of quinaldine ethiodide on the cathode potential-current relationship at low current densities.

densities and at 1 amp/dm² in the case of quinaldine ethiodide and ethylenecyanohydrin. The results under both sets of experimental conditions were essentially the same. The similarity was just as good with coumarin, pyridine, and benzenesulfonic acid.

Potential measurements in N HCl.—The purpose of these experiments was to compare the adsorption by nickel of a number of compounds with the effect of the same compounds on the cathode potential during electrodeposition of nickel. It was assumed initially from the results of Hackerman and Sudbury (1) that the change in potential of a metal in the presence of organic compounds was a direct measure of adsorption. However, as pointed out later, this assumption was checked by measuring the adsorption of six of the compounds by finely divided nickel.

Preliminary experiments were carried out to determine the change in the potential of a nickel

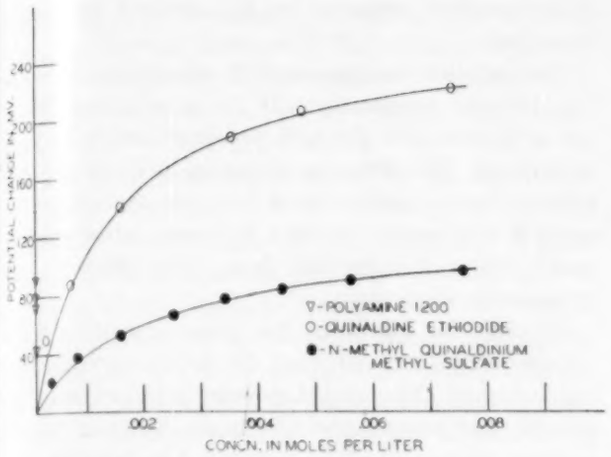


FIG. 12. The change in the noble direction of the electrode potential of a mechanically polished cylinder of nickel immersed in *N* HCl upon addition of organic compounds.

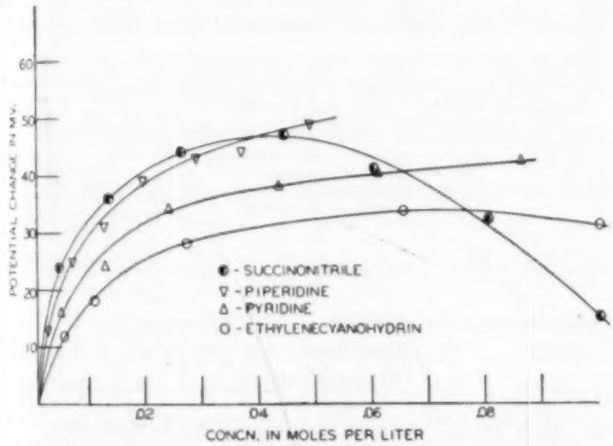


FIG. 13. The change in the noble direction of the electrode potential of a mechanically polished cylinder of nickel immersed in *N* HCl upon addition of organic compounds.

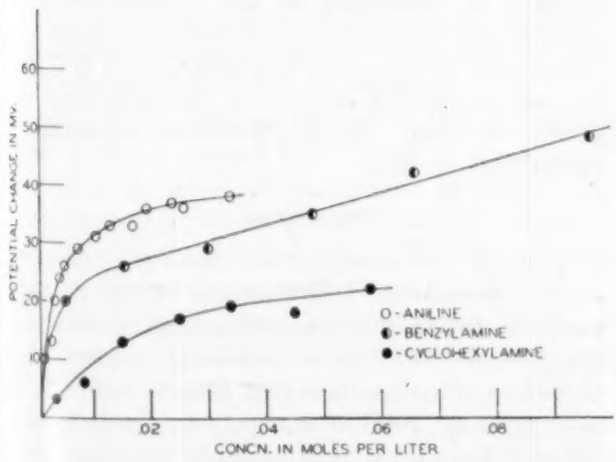


FIG. 14. The change in the noble direction of the electrode potential of a mechanically polished cylinder of nickel immersed in *N* HCl upon addition of organic compounds.

cylinder in the Watts plating bath in the absence of current flow. Compounds such as quinaldine ethiodide and Polyamine 1200 decreased the electrode potential by as much as 50–100 mv. However, compounds such as aniline, isoquinoline, and ethylenecyanohydrin decreased the potential only 5–10 mv. The relative effects of the latter compounds were qualitatively similar to those observed in the measurements of the cathode potential at 30°C and 1 amp/dm².

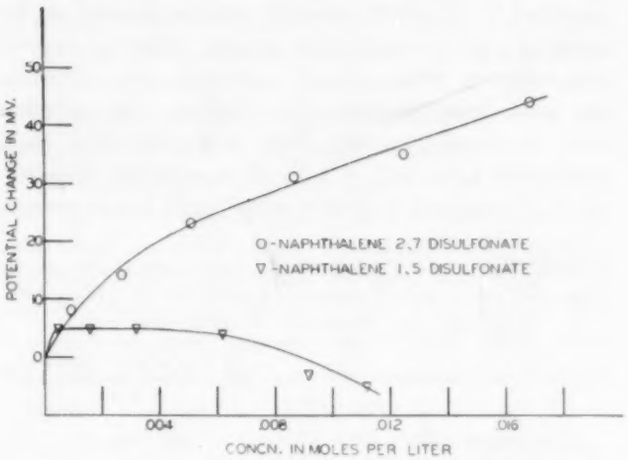


FIG. 15. The change in the noble direction of the electrode potential of a mechanically polished cylinder of nickel immersed in *N* HCl upon addition of organic compounds.

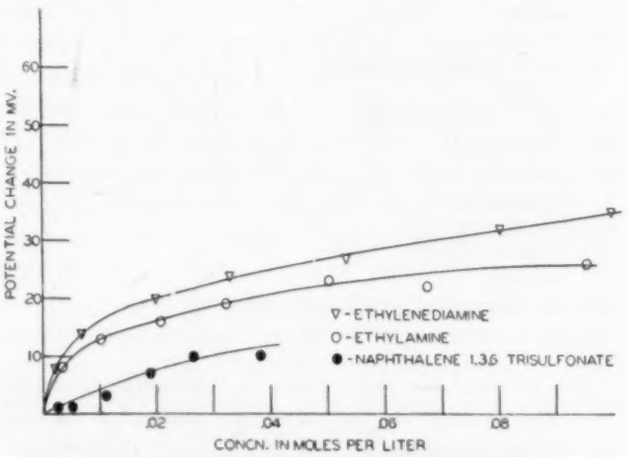


FIG. 16. The change in the noble direction of the electrode potential of a mechanically polished cylinder of nickel immersed in *N* HCl upon addition of organic compounds.

Experiments were conducted next in HCl as organic compounds were added to the acid in increasing concentration. The potential increase was much greater in HCl than in the Watts bath. Several difficulties were encountered in these experiments which necessitated the adoption of a strictly uniform experimental routine. The potential tended to increase with time of immersion in the acid and dropped greatly as the solution was stirred. The potential rose again in a period of 1–2 min as the

solution became quiescent. The following experimental procedure was used to compensate for the change in potential with time. The nickel cylinder was immersed in the acid, the solution was vigorously stirred every 7 min, and the potential was noted 1, 4, and 6 min after each stirring. No organic material was added at the start of an experiment until the potential changed very little with each successive stirring. In general, 20–40 min were required to obtain a potential which changed of the order of a mv in each 7-min period. A similar routine was followed when organic materials were added to the acid. Immediately after addition, the solution was vigorously stirred. The potential was then measured 1, 4, and 6 min after stirring. Organic material was added at the end of each 7-min period.

TABLE III. *Relative effects of 15 organic compounds on the potential of a nickel cylinder suspended in* HCl. *The compounds are arranged in decreasing order*

Compound	Division in which compound fell in cathode potential study; See Table I
1. Polyamine 1200	8
2. Quinaldine ethiodide	7
3. *N*-methyl quinaldinium methylsulfate	(?), but probably in 7
4. Succinonitrile	5
5. Piperidine	1
6. Aniline	4
7. Pyridine	5
8. Naphthalene 2,7 disulfonate	2
9. Ethylenecyanohydrin	4
10. Benzylamine	2
11. Cyclohexylamine	1
12. Ethylenediamine	2
13. Ethylamine	1
14. Naphthalene 1,3,6 trisulfonate	1
15. Naphthalene 1,5 disulfonate	2

No attempt has been made in the results to separate the change in the electrode potential caused by the addition agent and the natural drift which occurred with time in the absence of the agent. In all cases, the change in the potential was much greater than could be accounted for on the basis of a natural drift in the electrode potential. The data are plotted in Fig. 12–16. The relative effects of the same 15 compounds on the cathode potential are summarized in Table III.

Adsorption of organic compounds by Raney nickel.—An attempt was made first to measure the adsorption of organic compounds by finely divided, commercial nickel powder. In several cases, as much as 100 grams of powder was used with a solution volume of 100 ml, but no adsorption could be detected. Experiments were then confined to Raney nickel powder prepared by the method previously described.

The powder had measurable adsorption activity, but different preparations of the powder had different activities, and the activity decreased with time of storage. The extreme chemical activity of this powder was demonstrated by the facts that it reacted with water to form hydrogen after storage under water for several days, and that it was pyrophoric when dry.

In order to minimize the errors resulting from change in activity with time, the following procedure was adopted. The nickel powder was prepared in one day and was allowed to remain in strong caustic solution overnight. The powder was washed free of alkali on the following day and was stored overnight under water. All experiments with the preparation were conducted on the third and fourth day after preparation. Although the results were not identical in different preparations, the relative amounts of adsorption of the compounds were qualitatively the same in the different preparations. The results of this study are summarized in Table IV, and comparison is made in the table with the results obtained in the potential experiments carried out in HCl.

TABLE IV. *Comparison of the adsorption of organic nitrogen compounds by Raney nickel powder and the effects of these compounds on the potential of a nickel cylinder in* HCl

	Ability of compound to be adsorbed by nickel powder in decreasing order	Effects of compound on potential of nickel in HCl in decreasing order
Greatest effect	Quinoline	Quinaldine ethiodide
Intermediate effect	Pyridine Piperidine Ethylenediamine	Piperidine Pyridine
Smallest effect	Cyclohexylamine Ethylamine	Ethylenediamine Ethylamine Cyclohexylamine

Discussion

Origin of change in cathode potential caused by organic compounds.—The increase in the cathode potential during the electrodeposition of nickel in the presence of organic molecules implies that nickel is electrodeposited with greater difficulty in their presence. Additional energy in the form of a higher voltage must be supplied to the nickel ions in order to form the deposit at a predetermined current density. Four possible explanations for this effect are: (*a*) changes in cathode film *p*H produced by the addition agent; (*b*) changes in concentration of nickel ions in the cathode film caused by complex-

ing; (*c*) increase in ohmic resistance of the cathode film caused by the presence of the organic compound; and (*d*) adsorption of the organic compound with resultant change in the ease with which the process, $Ni^{++} + 2e \rightarrow Ni(cryst.)$ occurs.

It is known from experiments carried out in this laboratory that the cathode potential in an unadulterated Watts bath at a fixed current density increases with increase in *p*H. The following experimental evidence suggests strongly that the results in the presence of the organic agents cannot be explained solely on the basis of an increase in the *p*H of the cathode film. In many cases, the cathode potential increase was too great to be accounted for by *p*H change at the metal surface. Agitation had the same effect on the cathode potential as an increase in concentration of the compound. In an unadulterated Watts bath, or in the presence of compounds which had little or no effect on the cathode potential, agitation had no effect. Since the solution was buffered with boric acid at a *p*H of 4, it would be expected that agitation should maintain the *p*H at the surface of the cathode closer to 4. If a *p*H change was the cause of the increase in the potential, the potential should have decreased with agitation instead of increased. Further evidence against an explanation based on *p*H changes in the cathode film include the following facts: (*a*) acidic compounds such as the sulfonates and benzoic acid increased the cathode potential; (*b*) compounds of similar basicity, such as aniline and isoquinoline, were very different in their effects on the cathode potential; and (*c*) the strongly basic compounds such as ethylamine, piperidine, and cyclohexylamine had a negligible effect on the cathode potential. The data prove that change in *p*H is not the major cause of the potential increase, although it is possible that *p*H effects may make a small contribution to the over-all effect.

Many of the compounds used in this study are known to form complex ions with nickel in aqueous solution. A decrease in concentration of nickel ions would have the effect of increasing the cathode potential. Here again the great effect of stirring militates against an explanation based on the formation of complex ions. Stirring should have the effect of decreasing the thickness of the diffusion layer at the cathode and thus increasing the effective concentration of nickel ions at the surface. If complexing were the sole explanation for the experimental results, it would be expected that stirring would have the effect of lowering the cathode potential. On the basis of this evidence and the great changes in concentration required to account for some of the changes in potential, complexing phenomena are of negligible importance in explaining the results.

Results with ethylenecyanohydrin, quinaldine ethiodide, coumarin, and pyridine at current densities of the order of 10^{-2} amp/dm^2, which represents a total current of approximately 10^{-3} amp, indicate that ohmic resistance is not a significant factor. Under these experimental conditions, the *IR* drop would be negligible because of the very small currents passing. Yet, as shown in Fig. 7 and 8, the change in cathode potential was of the same order of magnitude as that noted at 1 amp/dm^2. It is concluded that the *IR* contribution to the measured potential is not a major factor.

The experimental evidence supports the conclusion that the change in the cathode potential is caused by adsorption of the organic compound on the surface with a resultant change in the ease with which the over-all deposition process can take place. The experiments with Raney nickel furnish proof that compounds most effective in increasing the cathode potential were more readily adsorbed than those less effective in increasing the cathode potential. It is also a well-known fact (2) that, during deposition of nickel under commercial conditions, organic agents are occluded in the deposit. The large amounts of carbon and/or sulfur found in the deposit in some cases imply that the addition agent was present at the surface during deposition. The potential experiments in HCl indicate that these organic compounds had the ability to interfere with the electron transfer at the solution-nickel interface. X-ray measurements (3) indicated that the organic compounds having the greatest effect on the cathode potential also have the greatest effect on crystal growth of the deposit. It appears impossible to decide at the present time if the change in the cathode potential is a result of interference with the electron transfer from the cathode to the nickel ions in solution, or of interference with crystal growth of the discharged atoms.

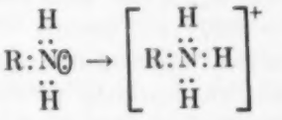
Relation of cathode potential results to molecular structure of the organic compounds.—The comparative effectiveness of chemical groups in increasing the cathode potential during the electrodeposition of nickel decreased in the following order: nitrogen in conjugated bicyclic ring, nitrogen in conjugated monocyclic ring, nitrile, aldehyde, amino, nitro, tertiary amine, sulfone, sulfonylamide, sulfonate, carboxyl, ketone, and phenolic or alcoholic hydroxy. Table I shows that all compounds containing an acid group such as sulfonate, carboxyl, phenolic —OH, etc., are confined to groups 1–3. All compounds containing solely acid groups such as phenol, benzoic acid, and the sulfonates had only a slight effect on the cathode potential. Introduction of a

basic group such as N in a conjugated ring, nitrile, or amino into a compound having an acid group had the effect of increasing the cathode potential. Introduction of a basic group in the ortho position had little effect, in the meta position an intermediate effect, and in the para position the greatest effect. In the case of acid groups meta or para to a basic group on the benzene ring, the effect of the disubstituted compound on the cathode potential was intermediate to that of the monosubstituted acid compound and of the monosubstituted basic compound. Quantitative data showing this generalization are given in Fig. 5 and 6. It was also observed that the effect of *p*-hydroxybenzonitrile was intermediate to the effects of phenol and benzonitrile; the effect of *p*-aminophenol was intermediate to the effects of phenol and aniline; and the effect of *m*-sulfonitrobenzene was intermediate to the effects of benzene sulfonic acid and nitrobenzene.

The data summarized in Fig. 3 for methylamine, sec.-butylamine, triethylamine, and dodecylamine point out the influence of size of the molecule. The effect of the compound on the cathode potential increases in this series of alkyl amines with the size of the molecule. Table II in a very general manner also outlines the importance of molecular size. The large compounds such as Magenta dye, Polyamine 1200, and the bicyclic nitrogen compounds had a much greater effect than the alkyl or substituted benzene compounds. Qualitative experiments with phenanthroline and acridine indicated further that they were even more effective than the bicyclic nitrogen compounds. The inability of molecular size to account satisfactorily for all the results is shown in a striking manner in Fig. 4. The saturated compounds piperidine and cyclohexylamine had a negligible effect on the cathode potential, whereas the unsaturated compounds of similar size, such as pyridine and aniline, had an appreciable effect. Table I shows that small compounds such as thiourea, ethylenediamine, and propionitrile were much more effective than larger compounds such as dodecylamine or triethylamine.

The following discussion is limited to those compounds which contain only basic or neutral groups. Forty-nine of the 76 compounds fall in this class. The compounds containing acidic groups are omitted from the discussion because the negative charge of the ion in the solution is a complicating factor.

A fruitful correlation of the results has been found in the concept of "available pairs of electrons." The definition is as follows: "Available pairs of electrons are those which are capable of being shared with other atoms through association or chemical reaction without breaking completely the original bond between the atoms involved." In the case of an alkyl amine group, for example, there exists a single pair of unshared electrons which is available for association:



The available pair of electrons is circled.

In the case of the nitrile group, there are 3 pairs of electrons which are "available" for sharing with other atoms without breaking completely the original bond between the carbon and nitrogen atoms as shown in the following diagram:

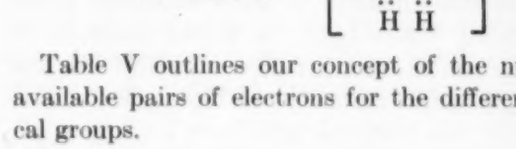


Table V outlines our concept of the number of available pairs of electrons for the different chemical groups.

TABLE V. *Number of available pairs of electrons in nonacidic groups studied in this investigation*

Chemical group	Number of available pairs of electrons
—CN	3
—S— (sulfidic)	1
—NH—	1
$—NH_2$	1
N in ring compound	1
Double bond	1
—CHO	1
C=O	1
—OH (alcoholic)	0

A list of the nonacidic compounds in approximate order of their decreasing effect on the cathode potential and the total number of available pairs of electrons is given in Table VI. This table shows that the compounds most effective in increasing the cathode potential were those which have the greatest number of available pairs of electrons. The correlation is excellent with the exception of the three structurally similar compounds, *N*-ethyl, *N*-beta-hydroxyethyl aniline, *N*,*N* di (beta-hydroxyethyl) aniline, and diethylaniline. The rather poor correlation in the case of these three compounds may be explained in part by the fact that the nitrogen atom is sterically hindered.

The significance drawn from this correlation is that attachment of an organic compound to the nickel surface during plating is dependent, in part, on the presence in the molecule of pairs of electrons available for interaction with the surface atoms of the metal. The strength of attachment of the molecule to the surface, or perhaps the area covered

TABLE VI. *Relation of the cathode potential increase to the number of available pairs of electrons in the molecule*

Approximate order of decreasing effect on the cathode potential	Total number of available pairs of electrons
1. Polyamine 1200	29
2. Polyamine 650	16
3. Magenta dye (quinoid form)	13
4. Melamine	9
5. Quinaldine ethiodide*	6
6. Isoquinoline	6
7. Quinoline ethiodide*	6
8. Tetraethylenepentamine	5
9. *o*-Phenylenediamine	5
10. *N*-methyl isoquinolinium methylsulfate*	6
11. Quinaldine	6
12. *m*-Phenylenediamine	5
13. Quinoline	6
14. *p*-Phenylenediamine	5
15. Coumarin	5
16. Pyridine	4
17. 2,4,6 Collidine	4
18. Alpha-picoline	4
19. Succinonitrile	6
20. Benzonitrile	6
21. Sym.-diethylthioures	3
22. *p*-Aminobenzonitrile	7
23. Diethylenetriamine	3
24. Aniline	4
25. Nitrobenzene (probably reduced to aniline)	4
26. Glycolonitrile	3
27. Ethylenecyanohydrin	3
28. Gamma-hydroxybutyronitrile	3
29. Benzaldehyde	4
30. Thiourea	3
31. Propionitrile	3
32. Acrylonitrile	4
33. Benzylamine	4
34. Lactonitrile	3
35. Furfural	3
36. Dodecylamine	1
37. *N*-ethyl *N*-beta-hydroxyethyl aniline	4
38. *N*,*N* di(beta-hydroxyethyl) aniline	4
39. Diethylaniline	4
40. Piperidine	1
41. Cyclohexylamine	1
42. Ethanolamine	1
43. Acetylacetone	1
44. Triethylamine	1
45. Diethylamine	1
46. Sec.-butylamine	1
47. Methylamine	1
48. Ethylamine	1
49. Ethanol	0
50. Quinone (probably reduced to hydroquinone)	2 (0) for hydroquinone

* A value of 1 has been added to take into account the positive charge of the tetrammonium ion.

by the molecule on the surface, is dependent largely on the number of pairs of available electrons within the molecule. It is evident, however, that the relative positions of the available pairs of electrons, the size and shape of the molecule, and relative tendency of these electrons to interact with nickel atoms in the surface are also factors which must be considered.

Brightening of the deposit.—The compounds which caused appreciable brightening of the deposit are given in Table II. The relation between molecular size and the minimum concentration of the organic compound required to cause brightening is shown in the following condensation of Table II.

Type of compound	No. of representatives	Average minimum concn. required to brighten deposit
		m/l
Very large compounds	2	0.000057
Bicyclic compounds	13	0.00085
Monocyclic compounds	12	0.008
Short chain alkyl compounds	8	0.003

The two acidic monocyclic compounds, benzenesulfonic acid and benzenedisulfonic acid, appreciably raise the average minimum concentration for the monocyclic compounds. If these two compounds are not included, the average minimum concentration required to brighten the deposit is approximately the same for both the monocyclic compounds and the short chain alkyls. The generalization is drawn that the minimum concentration of an organic compound required to impart appreciable brightness to a nickel electrodeposit decreases with increase in molecular size of the compound.

The cathode potential increase at which brightening was first observed ranged from 14 to 97 mv for the compounds listed in Table II. Twenty-five of the 35 compounds fell in the 20 to 50-mv range, 3 fell in the 14 to 19-mv range, and 7 fell in the 51 to 97-mv range.

Cathode potential-concentration curves are presented in Fig. 9 and 10 for 1 naphthylamine 4,8 disulfonic acid, and lactonitrile. The concentration and the cathode potential increase for the first sign of brightening is denoted by a two-headed arrow for both of these compounds. Extrapolation of the linear portion of the curve (dotted line) to zero concentration gives a cathode potential increase approximately the same as that observed for the first sign of brightening. A similar effect was noted for 24 of the 36 compounds which brightened the deposit. The remaining 12 compounds exhibited concentration-cathode potential curves which had no linear segment, and were thus not susceptible to the same treatment.

These results are interpreted as follows. The

cathode potential concentration curves are considered to represent adsorption. It is suggested that the increase in cathode potential is a qualitative measure of the number of nickel atoms in the surface that are covered with organic material. Since brightening was first observed at a cathode potential increase of 20–50 mv for the majority of compounds, the suggestion is presented that a minimum fractional coverage of nickel surface atoms is necessary for brightening to occur. Good bright plating can only occur when the concentration of the agent is sufficient to exceed this minimum fractional coverage of the surface. Since bright plating is a dynamic process, the surface is continuously changing, and new organic molecules must be supplied in order to replace those lost by decomposition, occlusion in the deposit, or desorption and diffusion away from the cathode. Fractional coverage represents a statistical state. An estimate of the order of magnitude of the extent of this fractional coverage is not possible with the data at hand. It is worth noting however, that if the curves shown in Fig. 9 and 10 are considered analogous to those obtained in gaseous adsorption, the fractional coverage necessary for brightening would represent slightly less than complete unimolecular coverage of the surface.

Significance of results to commercial bright plating.—It was the fond hope at the start of this study that a correlation between the cathode potential increase and the brightness of the surface would be found. No simple relationship was found, but several qualitative observations can be made. First, in all cases the deposition of nickel in the bright form was accompanied by a cathode potential increase of the order of 20 or more mv. Several commercial bright plating baths yielded cathode potential increases of approximately 30 mv. No bright deposits were observed in the absence of an increase in the cathode potential. However, an increase in the cathode potential did not necessarily lead to a bright deposit. Compounds such as benzaldehyde, aniline, 1,3,6 collidine, melamine, and the phenylenediamines were very effective in raising the cathode potential, but were completely ineffective in developing a bright deposit. X-ray measurements (3) indicated, however, that all compounds which had an effect on the cathode potential had a great effect on the crystal growth of the deposit. Addition agents effective in increasing the cathode potential had the ability to decrease the crystal size of the deposit or to alter the type and/or degree of preferred orientation. Compounds most effective in increasing the cathode potential both decreased the crystal size and changed the type of preferred orientation.

Commercial platers divide addition agents for convenience into two types, "carriers" and "brighteners." Carriers are considered to be compounds which may be added to a plating bath in rather large concentrations without conferring deleterious effects to the deposit, but which are ineffective in developing a fully bright deposit. Brighteners are considered to be compounds which may be added to a plating bath only in small concentrations without conferring deleterious effects to the deposit, and which are very effective in developing a fully bright plate in the presence of a carrier. The division between these two groups of compounds was clearly shown in the cathode potential experiments. The carriers, such as the benzene sulfonates, naphthalene sulfonates, saccharin, and *p*-toluenesulfonylamide, had the following characteristics in common: they were relatively ineffective in increasing the cathode potential; the cathode potential rose 15–45 mv at low concentrations and then changed very little with further increases in concentration; the deposits were bright under many plating conditions, but were far from mirror-bright; and they did not cause the deposit to crack and peel. The brighteners such as the conjugated nitrogen ring compounds, nitriles, and polyamines had the following characteristics in common: they were very effective in increasing the cathode potential; the cathode potential continued to increase sharply with increases in concentration; the deposits were mirror-bright under limited experimental conditions; and the deposit tended to crack and peel when the cathode potential increase exceeded approximately 30 mv.

An excellent relationship existed between the physical properties of the deposit and the cathode potential increase. The generalization was drawn that high cathode potential increases coincided with brittleness, cracking, and peeling of the deposit. It is inferred that commercially acceptable bright plating baths should avoid concentrations of addition agents which would lead to high cathode potentials. Similar deleterious effects on the physical properties of the nickel electrodeposit in the presence of compounds yielding high cathode polarizations had been observed previously by Raub and Wittum (4).

The excellent relationship between molecular structure and cathode potential increases observed herein should be of value in estimating concentrations of agents to be used in the routine testing of a large number of chemical compounds as bright plating agents.

Acknowledgment

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Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the JOURNAL.

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Electroluminescent Zinc Sulfide Phosphors[1]

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ABSTRACT

The preparation of blue, green, and yellow electroluminescent zinc sulfide phosphors is described. The blue and green phosphors contain copper and lead, with the color being determined by the copper and chloride concentration. The yellow phosphors are triple-activated, containing copper, lead, and manganese.

INTRODUCTION

This paper describes the preparation and some of the properties of certain electroluminescent phosphors (EL phosphors). Green and blue EL phosphors are sensitized by a small amount of lead, combined with copper in amounts which are several times the order of magnitude of the amounts normally used for activation in fluorescent or cathodoluminescent zinc sulfides. The yellow EL phosphor contains a manganese activator, in addition to lead and copper, in approximately the same amounts as those present in the green EL phosphor. The phosphors also contain a controlled amount of chloride.

The only previously published papers[2] describing the preparation of electroluminescent phosphors are those of Destriau (1). Those phosphors are definitely different from the present materials, since Destriau made no addition of lead. A further difference lies in the fact that his phosphors contain, in addition to zinc sulfide, a very large amount of zinc oxide and, in fact, he reports that the best phosphors contained from 50 to 90 per cent zinc oxide. This very large amount of zinc oxide makes it possible that his phosphors are electroluminescent zinc oxide rather than electroluminescent zinc sulfide.

Although several other papers (2–5) have been published on the electroluminescence of zinc sulfide and zinc sulfoselenides, there has been no description in them of the method of preparation of the phosphors. Infrared stimulable phosphors using a combination of copper and lead as activators were described by Fonda (6) originally and there has been some further work on such phosphors published by Pearlman and coworkers (7). However, these phosphors do not show any electroluminescence even though both copper and lead are present. It is clear from the published data that these infrared phosphors are predominantly hexagonal in crystal structure, must be prepared in the presence of extremely large amounts of lead, approximately 0.01 to 0.02 gram atoms Pb per mole of ZnS, and must contain amounts of copper which are small in comparison to those normally used for fluorescent materials. Pearlman, for example, shows that the stimulability reaches its peak value at a copper content of approximately 5×10^{-6} gram atoms of copper per mole of zinc sulfide and the stimulability falls off seriously at a copper concentration ten times this value. In contrast to these infrared stimulable phosphors, the EL phosphors contain from 2×10^{-4} up to 2×10^{-3} gram atoms of copper per mole of zinc sulfide. No distinction need be made between amounts of copper added and copper retained, since little or no copper is lost either in firing or in after-treatment of the EL phosphors.

EXPERIMENTAL

Method of Preparation

Although several methods can be employed in mixing the raw materials for EL phosphors and several firing methods have been used successfully, most of the work described in the present paper was carried out by a method employing dry blending of the raw materials, combined with firing in a current of nitrogen. The basic raw material was unfired zinc sulfide (Sylvania Cathodo-Luminescent Grade), which is prepared with an appreciable content of chloride, present either as ammonium chloride or zinc chloride. The other raw materials used in minor amounts were zinc oxide (New Jersey Zinc Company Green Seal or Kadox) cupric oxide, or cupric carbonate (C.P. quality), lead carbonate (C.P. quality), and manganous carbonate (Mallinckrodt Ultrapure). The particular materials used for introducing the activators are not critical

[1] Manuscript received May 1, 1953. This paper was prepared for delivery before the New York Meeting, April 12 to 16, 1953.

[2] Footnote added in print: Papers presented at the Spring Meeting of The Electrochemical Society by H. C. Froelich and by P. Zalm, H. A. Klasens, and G. Diemer describe the preparation of lead-free electroluminescent phosphors with a hexagonal structure. H. C. Froelich's work has been published in brief in *J. Opt. Soc. Amer.*, **42**, 982 (1952) and **43**, 326 (1953).

and nearly any pure compound of copper, lead, or manganese can be employed. Appropriate amounts of these raw materials were weighed out and mixed by dry blending in a tumbling drum, followed by hammermilling and a repetition of the tumbling.

The powders were fired in silica trays. These trays were passed through a heated silica tube; they were loaded in one end of the tube and removed from the other through airlocks. A stream of nitrogen was passed through the tube countercurrent to the direction of passage of the phosphor trays.

After firing, the phosphor was crushed and subjected to a treatment in hot acetic acid, followed by washing with more dilute solutions of acid, and finally with hot water. This acid treatment removed any free zinc oxide, either added to the raw material mixture or formed from the zinc sulfide during firing. The effect of this treatment was to increase the brightness and to reduce considerably the current through an electroluminescent lamp.

Method of Testing

The electroluminescent phosphors prepared in this work were tested by mortar grinding 1.25 grams of phosphor with 1 ml of low acid number castor oil. The suspension was placed on a metal plate 1½ in.² and a conducting glass placed over the phosphor-covered area. Provision was made for holding the conducting glass at a fixed spacing of approximately 0.005 in. above the metal plate.

The search unit of a Photovolt meter (Model 520M) containing a 1P22 photomultiplier tube was held in a fixed position above the test area. The brightness and current were measured at several voltages after the test plaque had been aged for 5 minutes at 500 volts. The brightness readings were in arbitrary units, while the current readings were in microamperes. Green phosphors with a plaque brightness of 300, as in Fig. 1, have given lamps with an output up to 20 ft-L at 60 cycles and 750 volts when measured with a Luckiesh Taylor meter; however, details of lamp construction may have a major effect on the brightness obtained.

The color of the emitted light was determined by placing Corning Glass Filters #5551, 3484, and 2424 in succession over the lighted area of the test plaque held at 500 volts, and measuring the light output through these filters. The ratio of the light through the blue filter to that through the yellow filter is referred to as the color ratio. These values are again arbitrary, depending on the spectral sensitivity of the phototube. Blue EL phosphors generally give a color ratio between 3.0 and 5.5, while green EL phosphors have a color ratio between 0.5 and 1.5. These ranges correspond to a shift, in one case, from light blue to a deep blue and, in the second case, from a yellow-green to a bluish-green.

Green Electroluminescent Phosphors

Good quality green EL phosphors contain copper between about 4×10^{-4} and 1.5×10^{-3} gram atoms of copper per mole of zinc sulfide. The daylight color of the fired materials is quite dependent on the copper content, the powders becoming increasingly dark as the amount of copper is increased. Below approximately 2×10^{-4} gram atoms of copper per mole of zinc sulfide, there is little or no electroluminescence. Copper in excess of this gives very good electroluminescence, the brightness rising to a maximum and then falling off slowly as the copper content is increased. With constant chloride and lead contents in the raw material mixture, the color ratio varies somewhat with copper content, low copper leading to blue-green phosphors, and high copper leading to yellow-green phosphors. The effect of copper content on the electroluminescent phosphors is shown in Fig. 1 for a typical series fired at 815°C. At higher temperatures, somewhat different values are found for brightness and color ratio, especially when the copper content is low. Firing temperatures can be varied from 750° to 1050°C; below 750°C there is little green electroluminescence and above 1000°C electroluminescence begins to fall off rather seriously.

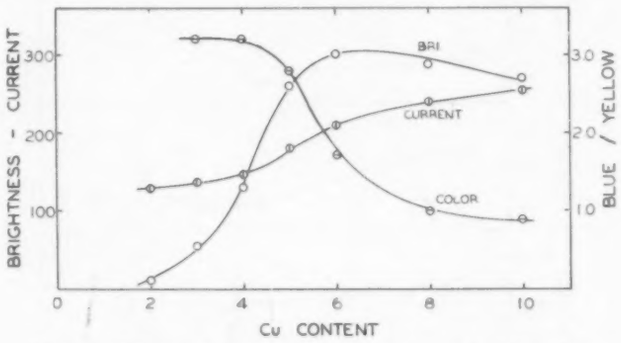

FIG. 1. Effect of copper content on relative plaque brightness, plaque current, and color ratio of EL phosphors. Copper concentration in units of 10^{-4} gram atoms Cu per mole ZnS.

X-ray powder diffraction patterns show that the crystal structure of the phosphors is essentially cubic, although there are small amounts of hexagonal zinc sulfide present, especially in phosphors fired at temperatures above 1000°C. During the firing, a considerable amount of the chloride originally present in the raw material mixture is lost, largely as zinc chloride, and it carries with it most of the lead. Fig. 2 shows the effect of firing temperature on the lead and chloride content of a typical phosphor containing 9×10^{-4} gram atoms of copper per mole

of zinc sulfide, together with data on brightness and color ratio. The increase in lead and chloride has been found repeatedly at temperatures above 1000°C. It may be associated with the partial transition to a hexagonal structure at these temperatures.

It is obvious that the brightness of the electroluminescence does not vary directly with the lead content. However, further tests have shown that lead or some equivalent element must be present for satisfactory electroluminescence in the types of phosphor described here, so it can be stated that lead contents above 2×10^{-6} gram atoms of lead per mole of zinc sulfide in the finished phosphor are

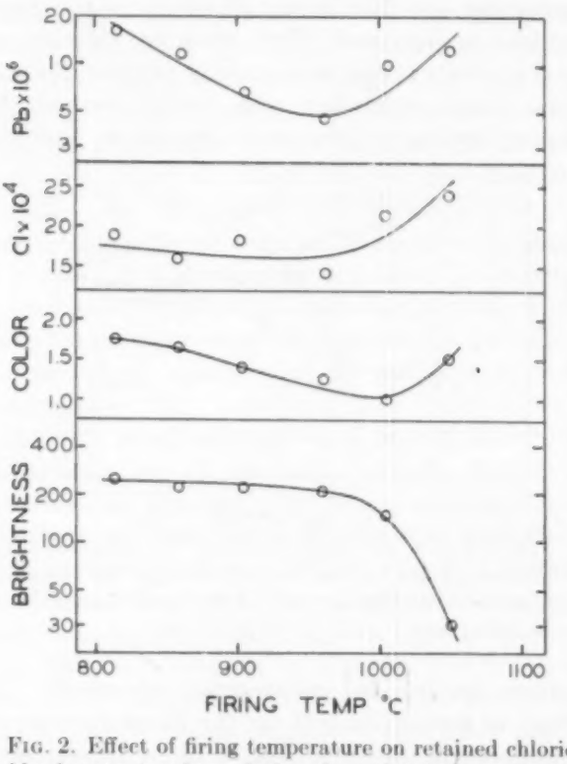

FIG. 2. Effect of firing temperature on retained chloride and lead content and on relative plaque brightness and color ratio of EL phosphors containing $9 \cdot 10^{-4}$ gram atoms Cu per mole ZnS.

needed for electroluminescence, and that increasing the amount above this does not lead to greatly improved brightness. With phosphors containing relatively large amounts of copper, the body color of the powder is an excellent indication of the presence of lead. The phosphors free of lead or containing lead below the amount needed for electroluminescence are very light in color, while those containing sufficient lead are considerably darker. The same criterion holds for phosphors low in copper, but the effects are much less marked.

It is not possible to state definitely the amount of lead which must be added to the raw material blend for satisfactory electroluminescence because of the great loss during firing. This loss of lead is determined by such variables as temperature, time of firing, gas flow through the tube, and chloride content of the unfired ZnS. However, if conditions are standardized, reproducible results are very readily obtained. The amount of lead permissible varies from ½ to 2 times the optimum amount. (A typical green phosphor uses 0.002 gram atoms Pb per mole ZnS.) This allowable range of lead is much smaller than the range found in the fired phosphor. It is also possible to make bright electroluminescent phosphors by a two-step process. This involves, first, firing the zinc sulfide and zinc oxide with the copper, and, second, refiring the fluorescent powder with a lead compound to convert it into an electroluminescent material. In this two-step process, the amount of lead mixed with the fired powder is considerably less than that employed with the one-step process, but the amount found in the finished phosphor is about the same. The two-step process may also be used for blue and yellow EL phosphors.

The amount of chloride needed in the raw material mixture for green phosphors is not very critical; between 2 and 3 per cent by weight as chlorine is normally present. Any considerable reduction of the chloride content, however, leads to blue EL phosphors rather than green (see below).

Additions of zinc oxide were generally made to the raw material mixture in amounts of approximately 5 mole per cent of the zinc sulfide. The amount of zinc oxide used had little effect on the electroluminescence, and very bright phosphors can be made without the deliberate addition of any zinc oxide. However, uniformity was better when small amounts of zinc oxide were used. This result is quite different from that reported by Destriau (1), who indicates that very large amounts of zinc oxide were needed in his phosphors for satisfactory electroluminescence. Experiments in which phosphors were made using the procedures described by Destriau have given extremely low brightnesses compared with those obtained by the process described in this paper.

Blue Electroluminescent Phosphors

The blue electroluminescent phosphors are essentially a variant of the green phosphors, the changes consisting of a reduction of the copper content and a very careful control of the chloride content. In general, the blue phosphors contain from 3×10^{-4} up to 6×10^{-4} gram atoms of copper per mole of zinc sulfide, with the minimum permissible amount of chloride being retained after firing. Complete loss of chloride during firing gives very poor electroluminescence as well as poor fluorescence, while retention of an excessive amount shifts the color to a blue-green or green. The effect

of copper content on the color of the blue electroluminescent phosphors is shown in Fig. 3 for a series of powders made with the same raw materials and identical firing conditions.

The amount of lead added before firing is dependent on the raw materials and firing conditions to an even greater degree for blue phosphors than for green. Losses of lead and chloride during firing are interdependent, and the amount of lead must be controlled empirically so that the resultant phosphor has the optimum brightness and color.

Fig. 3 indicates the effect of firing conditions with variable copper content in the presence of constant amounts of lead and chloride. The color shifts caused by varying ratios of lead to chloride are reversible to a certain extent. Refiring a deep blue powder with lead chloride and ammonium chloride results in a green or blue-green EL phosphor, while refiring a blue-green powder with lead carbonate shifts the color to a deeper blue.

Yellow Electroluminescent Phosphors

The color of the electroluminescence can be shifted, in a continuous way, from green to a relatively deep orange by additions of manganese to a raw material mixture like that used for green EL phosphors. The color becomes a fairly brilliant yellow with 5×10^{-3} gram atoms of manganese per mole of sulfide and shifts to a deep orange at 2×10^{-2} gram atoms. Further increase of the manganese content leads to very little change in color, but there is a slight loss of brightness with higher amounts than 3×10^{-2}. The necessary concentrations of copper, lead, and chloride are nearly identical with those required for green EL phosphors. The processing conditions for this phosphor are very similar to those described for the green EL phosphor and need not be discussed in detail. X-ray powder diffraction patterns generally show a larger percentage of hexagonal material is present in the yellow EL phosphors than in either the green or blue, but the structure remains predominantly cubic. This can be interpreted to show that manganese lowers the transition temperature from cubic to hexagonal.

Fluorescent Behavior

Electroluminescent phosphors as described above show good fluorescence when excited by the usual blacklight sources, such as a high-pressure mercury lamp or a 360 BL fluorescent lamp, but the brightness is generally considerably below that obtained with phosphors designed for that type of excitation. This lower brightness is due in part to the fact that the copper content is considerably above the optimum amount for fluorescent excitation, but, in addition, the brightness is reduced by self-absorption of the fluorescent light by the phosphor itself. This is considerably increased by the presence of lead, as the change in body color of the powder indicates. The color of the fluorescent light is approximately the same as that obtained with electroluminescent excitation, although there are minor differences. It should be noted that the electroluminescent color depends on the frequency of the a-c power (5). The presence of lead in the phosphor not only affects the body color, but also affects the absorption between 330 and 400 millimicrons. This is shown in Fig. 4 which gives reflectance curves, determined on the Beckman Model DU Spectrophotometer with reflectance attachment, for several copper contents with and without lead present. It is obvious that copper introduces a strong absorption band and that this absorption

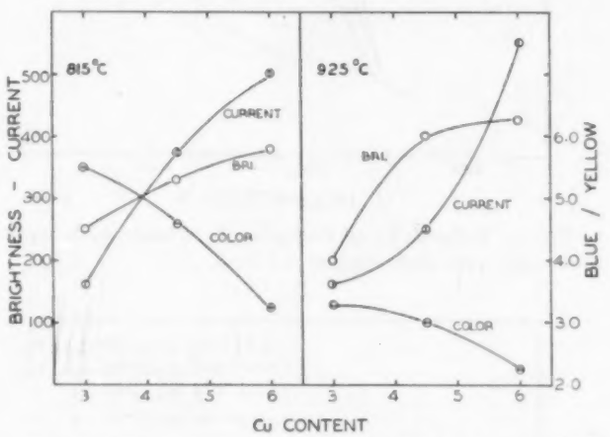

FIG. 3. Effect of copper content and firing temperature on relative plaque brightness, plaque current, and color ratio of EL phosphors with low chloride content. Copper concentration in units of 10^{-4} gram atoms Cu per mole ZnS.

band is enhanced by the presence of lead. This enhancement may, in part, be due to the precipitation of some copper sulfide in the surface layer. An absorption in the visible is caused by the presence of lead.

The fluorescent light with 360 BL excitation has been measured on a recording spectroradiometer for a series of phosphors with variable copper content, with and without lead. These are shown in Fig. 5. The phosphors during these measurements were at normal room temperature, approximately 20°C.

Previous work by Kroeger (8) and Leverenz (9) has shown that the color of the fluorescent light is dependent on copper concentration within this range. The present results differ from these previous ones, since the authors find no variation in the emission spectrum with copper content when the sample is free of lead. This can be attributed to some indeterminable difference in the method of prepara-

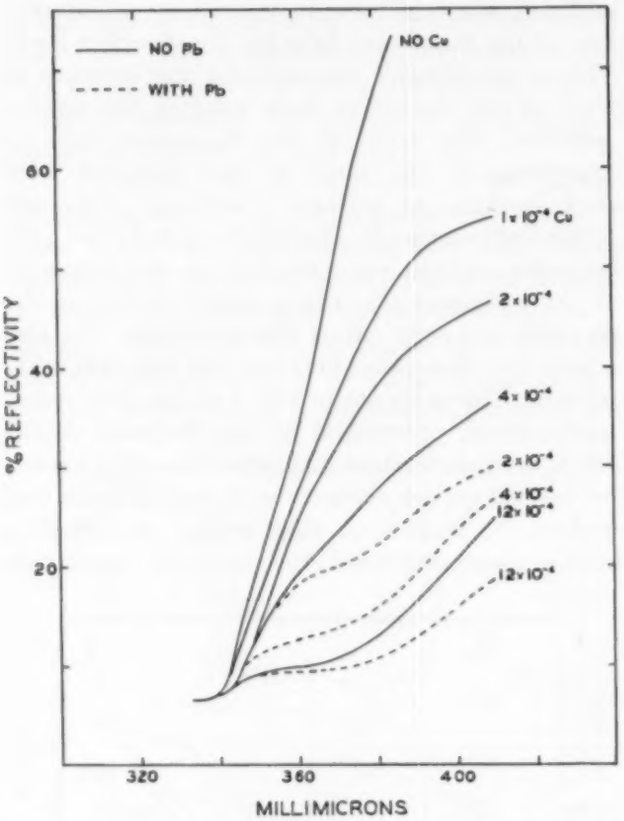

FIG. 4. Reflectivity of ZnS phosphors made with copper alone and with both copper and lead.

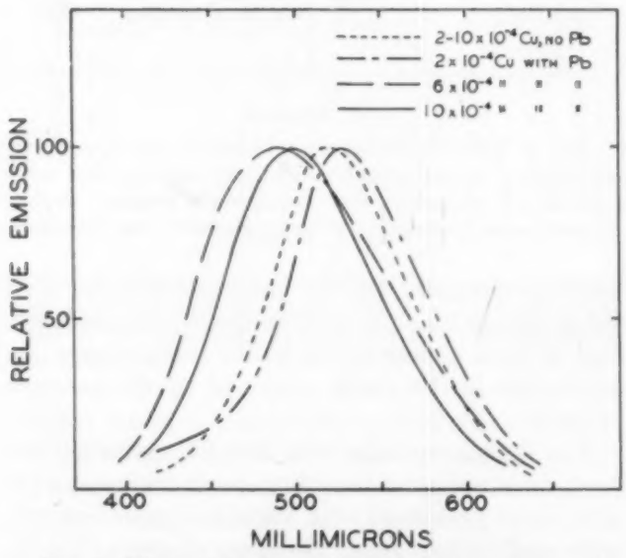

FIG. 5. Effect of lead on relative spectral energy distribution of fluorescent light emitted by ZnS phosphors with varying copper content. Copper concentration in units of gram atoms Cu per mole ZnS. Excitation by 360 BL fluorescent lamp.

tion. The addition of lead has a marked effect on the emission spectrum, the effect being dependent on the copper concentration. Phosphors with low copper are unchanged by the addition of lead, those with copper between 2×10^{-4} and 6×10^{-4} show blue emission predominantly, while higher copper content again leads to green fluorescence.

Discussion

The optical and the electrical properties of typical EL phosphors have been described in papers by Waymouth (5) and by Jerome and Gungle (10), and no further data will be reported in this paper.

It is interesting, however, to consider the role of lead in producing the phenomenon of electroluminescence in zinc sulfide phosphors containing copper. The observations that a certain minimum amount of lead or similar material and a certain minimum amount of copper are both necessary for good electroluminescence, and the marked change in daylight color of the phosphor when lead is present, especially when the copper content is high, indicates that a major function of the lead may be that of promoting the precipitation of an electrically conductive material either on the surface or in the body of the phosphor particles. The fact that the amount of copper must exceed a certain value would indicate that this conductive material is composed largely of copper sulfide in some form. The conductive material provides a source of free electrons in contact with the phosphor crystal. These free electrons are then available for injection into the crystal under the influence of an alternating field, even though the phosphor particle is completely surrounded by an insulating dielectric medium.

This analysis is supported by a further observation that many fluorescent zinc sulfides can be made to show electroluminescence if the phosphor particles are in contact with metallic electrodes. These electrodes provide the necessary source of free electrons. A further indication that the conducting material is copper sulfide lies in the fact that phosphors with extremely high copper contents show weak electroluminescence when suspended in a dielectric in an a-c field, even though no lead was added to the mixture before firing. This effect can be attributed to a limited solubility of copper in the zinc sulfide lattice. The exact value of this solubility is determined by the chloride content of the phosphor as indicated by experimental data. It shows that phosphors low in chloride exhibit some electroluminescence at an appreciably lower copper content than is required for the development of an equal amount of electroluminescence with higher chloride in the phosphor.

Conclusion

This paper has described electroluminescent phosphors, based on the activation of zinc sulfide with copper and trace amounts of lead, to give powders with a range of luminescent colors from

deep blue to a yellow-green. By addition of manganese, this color range can be extended to include yellows up to a deep orange, thus giving electroluminescent phosphors with a color range almost as wide as that of fluorescent or cathodoluminescent powders.

The method of preparation is simple, consisting of dry blending, firing in an inert, nontoxic gas, and then treating with dilute acetic acid. The resultant product is light cream in color and disperses readily in solutions of dielectric media. These can be used to manufacture electroluminescent lamps in a wide range of colors with brightnesses ranging up to 20 ft-L.

Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the JOURNAL.

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Electroluminescence of Insulated Particles[1]

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ABSTRACT

Some mechanisms are considered to explain the luminescence of a region on or near the surface of a semiconducting phosphor particle embedded in a dielectric medium and subjected to an electric field. The localization of the field, the presence of electrons in the conduction band, the color shift in some phosphors with frequency, the energy levels, and the efficiency of the phosphor are discussed.

INTRODUCTION

Lamps in which electroluminescent phosphor particles are embedded in an insulating medium and subjected to the action of alternating fields have been demonstrated within the past few years (1). The present paper considers some of the mechanisms which can be present in electroluminescence, and their effects. The mechanism may vary with different phosphors and different conditions of operation.

Zener (2) has shown that electrons can be excited from the valence band to the conduction band of a crystal by tunnelling, under the action of an electric field, and it would seem that excitation of the activator centers could then occur by a process such as the hole-migration of Klasens (3). McAfee (4) and his coworkers have shown that the critical field for appreciable Zener current is 2.5×10^5 volts/cm for a germanium crystal which has a forbidden gap of only about 0.75 ev, and indicate that the critical field varies as the $\frac{3}{2}$ power of the energy gap, which would make the critical field about 2.8×10^6 volts/cm for zinc sulfide, which has a gap of about 3.5 ev and about the same lattice constant as germanium. The critical field would presumably be somewhat less for tunnelling from activator levels.

However, excitation of the activator by impact with electrons accelerated to high enough energies by the field would appear to be possible at smaller field strengths than the above. The electrons could come from donor centers, either thermally or by tunnelling. But for the electron to be accelerated to the 2 or 3 ev energies necessary for excitation of an atom to "visible-emitting" levels, the field must be strong enough to accelerate the electron more quickly than it is de-celerated by impacts with the main lattice atoms. Putting the matter differently, the electron must gain energy from the field at a higher rate than it loses energy to the lattice (5, 6). The energy given up on impact with one of the main lattice atoms at the end of the mean free path must be less than that acquired by the electron in travelling through the mean free path.

Seitz (7) gives the mean free path in zinc sulfide as about 10 Å. The maximum phonon loss per impact with a lattice atom would be about 0.04 ev, and there would be only one phonon lost per impact (8). The critical field to provide an electron with a net gain of energy in traversing a mean free path would thus be about 4×10^5 volts/cm. Since the mean free path for 3-volt electrons is probably greater than 10 Å, the necessary field may be even smaller.

Electroluminescence occurs at average applied fields at least one order of magnitude below 4×10^5 volts/cm, however, and at such fields the luminescence has been found by Waymouth and Bitter (9) to occur in widely separated spots. Zalm (10) also reports luminescence confined to spots. Since the luminescence under ultraviolet excitation of the same crystals (9) is found to be fairly uniformly distributed, the activator concentration would seem to be uniform over the surface, and the nonuniformity would appear to be in the field.

There are various ways in which the field can be increased to the necessary value at certain parts of the crystal.

LOCALIZED HIGH FIELD

When the crystal is placed in contact with a metal or similar material of suitable conductivity and work function, there will be a high field in the semiconducting phosphor in the region of the contact. The acceleration of electrons through such a high field to excite atoms to luminescence has been shown, for example, by Piper and Williams (11), for electrodes in direct contact with the crystal. For that case, with direct current and an *n*-type phosphor crystal, the band diagram with the field applied would be as shown in Fig. 1.

Before the field is applied, the band is sym-

[1] Manuscript received May 25, 1953. This paper was prepared for delivery before the New York Meeting, April 12 to 16, 1953.

metrical, but the application of the field drops the band near the positive terminal and raises it near the negative, in accordance with the usual rectifier theory. It is at the negative electrode (11) that the excitation in such a case usually occurs, so the current flow through the crystal corresponds to that in the "back" direction of a rectifier, and is small. Electrons from the metal on the cathode side are excited thermally or by tunnelling to get over or across the barrier.

Electrons going over the barrier and falling toward the bottom of the conduction band lose energy as they drop a distance equivalent to, say, 3 ev. If the energy the electron gets between collisions is no greater than what it loses in each collision with the main lattice atoms, then the electron merely fritters its energy away to the lattice in small steps, and no luminescence results. But if the energy lost in each lattice collision is small compared with the energy gained between collisions, then the electron will continue to gain energy despite the lattice collisions, and will eventually get up to 3

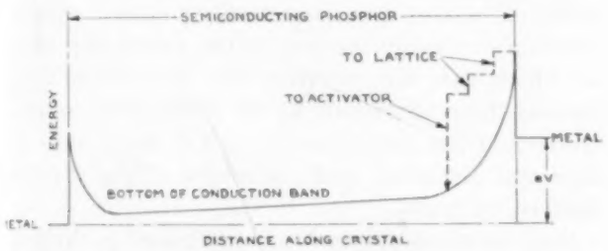

FIG. 1. Energy diagram of phosphor in contact with metallic circuit.

ev energy, which it can lose to an activator atom when it hits one, thereby exciting the latter to a light-producing level. Thus when an electron "rolls" far enough down a potential hill in a high enough field it can give up energy to activator atoms, if any are present, and these, on return to their normal states, can emit light.

It is important to note that for excitation of the activators in that manner, not only must the field be high enough, but also the voltage through which the electrons drop must have a value of several volts. This is true also of Zener excitation: it is not sufficient to have a high field over a distance which corresponds only to a small voltage.

At the positive end of the crystal, the electron is climbing up a potential hill, so it is acquiring potential energy and not kinetic. Activator atoms will not be excited by the electrons in that case—at least not until the electron rolls back down hill to give up its potential energy when the field is removed. When the current carriers are holes, however, they can gain kinetic energy in going up a potential hill.

If the phosphor particle is transferred from its position between metallic contacts to a position in an insulating dielectric medium, the effect of the increased field at the contacts will be lost, since there will be no contacts. Even putting a metallic or highly conducting layer over the entire outer surface of the crystal will not of itself restore the contact condition and make the crystal electroluminescent, because the presence of such a layer all over the crystal surface would merely short-circuit the particle. In fact, it has been shown that by dissolving away some of the conductive material left in the phosphor after firing, for example by dissolving away the free zinc oxide (12) or copper sulfide (13), the conductivity is reduced, but the luminescence improved.

If the deposit of metallic or other suitable material is confined to a few isolated spots on the surface

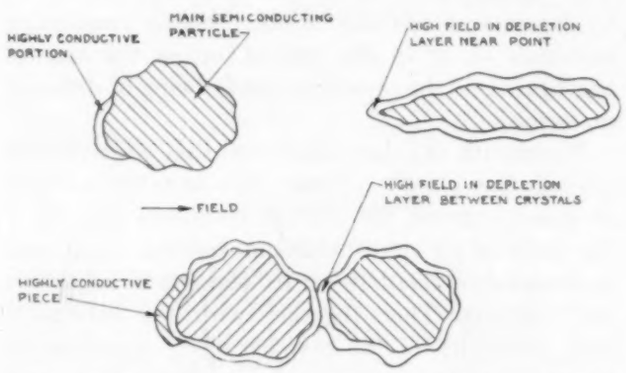
HIGHLY CONDUCTIVE PORTION
MAIN SEMICONDUCTING PARTICLE
HIGH FIELD IN DEPLETION LAYER NEAR POINT
FIELD
HIGH FIELD IN DEPLETION LAYER BETWEEN CRYSTALS
HIGHLY CONDUCTIVE PIECE

FIG. 2. Some methods of increasing field at spot on insulated phosphor crystal.

of the crystal or inside it, however, the field might be increased at such points by the contact-potential bending of the bands, by the increase of field at sharp points, or by the proximity of two such conducting spots to each other. Some of these effects are shown schematically in Fig. 2.

A high field can also be present between an area of traps or surface states and the main body of the crystal, and can be produced by the presence of a depletion layer over the surface of the crystal, or over part of its surface. The term "depletion layer" is here used in the Torrey-Whittmer (13) sense of a layer containing no donor or acceptor atoms, or containing a smaller concentration of them than the main body of the crystal. The layer is, in effect, an insulating layer over the main semiconducting body of the crystal, and when two crystals having such a layer are in contact, the layer will act like a dielectric between two "plates" of a condenser, and there will be a high field across it, as indicated in Fig. 2. If the two crystals are dissimilar chemically

or geometrically, the luminescence will vary with the polarity of the field.

If the depletion layer is depleted only of donor or acceptor atoms, but not of activator atoms, then electrons can be accelerated out of the main semiconducting body of the crystal and through the layer, where they can excite the activator atoms by impact. The same is true in the case of a long, slender needle-like crystal, where the high field at the point will cause similar effects in the depletion layer around the point. If the depletion layer were absent, the high field would be present in the embedding dielectric, where it would produce no luminescence.

In actual luminescent crystals, Waymouth and Bitter (9) have reported microscopic studies which show that electroluminescence sometimes occurs near the junction of two crystals in an aggregate, and near the ends of the more needle-like crystals, the crystals being embedded in a dielectric material. This luminescence can be due to a depletion layer, to deposits of metallic or other highly conducting materials on or in the crystal, or, in the case of aggregates, to the crystals actually being of different materials.

Waymouth (15) has also found that when several crystals are placed between two metallic contacts on direct current, the average resistivity may be of the order of 10^8 or 10^9 ohm-cm, but can sometimes be dropped to about 10^5 to 10^6 ohm-cm by adjusting the contacts. This, together with the extremely high resistivity of the crystals when measured as pressed powders, would make it appear that such crystals have a high-resistivity layer over most of their surface, with a break in the layer at certain points. The break could be considered as exposing an inner core of semiconducting material either directly or through a lower resistance portion which shorted through the layer, or it could be a simulated break caused by a high field at that point due to the geometry of the crystal.

Color Shift with Frequency

Once the electrons are accelerated in a sufficient field, they can excite activator atoms by impact. If the activator is merely excited to a state short of the conduction band, its electron stays with it, being merely shifted to a higher energy level within the atom. Once electrons are excited to such an intermediate or nonionized state, they will begin to drop back to their original states, the emitted light decaying according to the usual exponential laws. If the device is operated on alternating current, and if most of the electrons drop back before the next half-cycle begins, they will be available for excitation again during the next half-cycle, and the luminescence will increase linearly with frequency.

However, if the states to which the activator atoms are excited are metastable states, the atoms will drop back to normal more slowly, and may not all become de-excited before the beginning of the subsequent half-cycle, thus decreasing the concentration of unexcited activators available for excitation on that half-cycle. The sooner the subsequent half-cycle occurs, the fewer will be the number of activators available for excitation, and so the luminescence will approach a saturation value with frequency.

Waymouth (16) has found experimentally that in certain phosphors the blue emission rises linearly with frequency and the green emission saturates. Thus a phosphor of that type appears green at 60 cycles and blue at 3000 cycles.

The blue luminescence in such phosphors could result from excitation to an ordinary state, and the green from excitation to a metastable state. There is another way, however, in which the slower decay of the green could arise, and that is for the green-emitting activator to be actually ionized, with its electron excited all the way to the conduction band, in which case the electron will be carried away toward the positive side by the field. Such an electron could not return to an excited atom until the field was removed, and its return might then be delayed by traps.

Such an effect appears to be indicated in the light output curves shown by Waymouth and Bitter (17), which show that with certain green-luminescing ZnS:Cu, Pb phosphors immersed in a dielectric and excited by a d-c source, the light output does not occur until the field is removed. This seems to indicate that in such phosphors, the green-emitting activators are actually ionized. They lose their electrons, which are accelerated over to the other side of the active layer and held there by the field. When the field is removed, the electrons are released and return to the excited atoms, emitting light in the resultant recombination, as in the curves of Fig. 3.

A similar burst of light when the field is reduced is also reported by Zalm and Diemer (18), but apparently for direct contact to the crystal on direct current.

When the current is alternating, some of the electrons can be caught in traps deep enough to hold them for a period corresponding to more than one cycle, thereby reducing the number of recombinations and hence the concentration of unexcited green centers in phosphors having such traps. The traps will fill gradually during the first cycles of the applied voltage, until enough are filled to make the

number of electrons entering traps each cycle equal to the number leaving them. An increase in voltage will increase the number of electrons trapped by increasing the number of accelerated electrons per cycle, and will also free a larger number from traps each cycle so the equilibrium concentration of trapped electrons and, hence, of unexcited green centers will remain about the same. There will be no pronounced color change with voltage under such conditions.

A further indication that the blue centers emit at a different part of the cycle than the green is shown in the oscilloscope curves of Jerome (19), which show two peaks during each half-cycle. One set of these peaks is from light produced at one end of the crystal, the other at the other end. Each peak in one set is smaller than the corresponding peak in the other, due to the greater absorption suffered

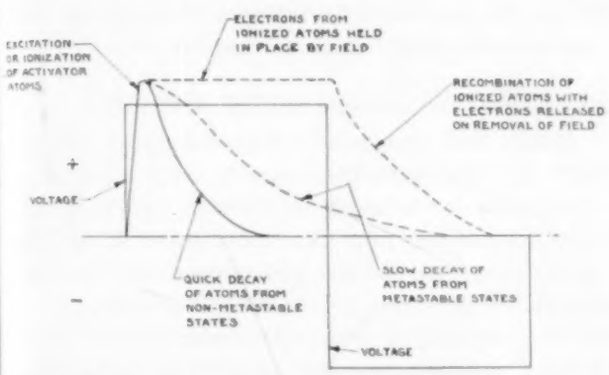
EXCITATION OR IONIZATION OF ACTIVATOR ATOMS
ELECTRONS FROM IONIZED ATOMS HELD IN PLACE BY FIELD
RECOMBINATION OF IONIZED ATOMS WITH ELECTRONS RELEASED ON REMOVAL OF FIELD
+
VOLTAGE
QUICK DECAY OF ATOMS FROM NON-METASTABLE STATES
SLOW DECAY OF ATOMS FROM METASTABLE STATES
VOLTAGE

FIG. 3. Schematic representation of excitation and de-excitation of ordinary, metastable, and ionized states of activators. In the ionized state, decay of excitation, and consequent light emission, does not begin until field is removed or reduced.

by the emission from the side of the crystal farthest from the observer. For the green phosphor, the higher peaks presumably represent predominantly green emission. This is only slightly absorbed in passing through the crystal, so the "green" peaks are not greatly different in height during opposite half-cycles. The other peaks, however, presumably represent the emission from blue centers (or to emission from copper excited to states below the conduction band), and suffer a much greater absorption, falling almost to zero during alternate half-cycles. This corresponds with Waymouth's reflectance curves (20), which show heavy absorption in the blue, and much smaller absorption in the green.

Thus, these curves indicate that the emission from the blue or nonconducting centers occurs at a part of the cycle about 90° out of phase with that corresponding to the emission from the green centers, as if the emission from one type of center was produced by excitation and de-excitation while the field was rising, and from the other type of center on recombination when it was falling.

The voltage curves given by Jerome (19) cannot be directly correlated in phase with the light output, because they were taken across the whole lamp, and the phase of the voltage across the active part of the phosphor is different.

In fact, the voltage across the active part of the phosphor particles will be roughly in phase with the current through the lamp, with the usual phosphor concentrations, because at low frequencies the crystal is largely resistive (18), and the series capacitance will be more important than the shunt capacitance as long as the ratio of the conductivity of the phosphor to the dielectric constant of the insulating medium has its usual values.

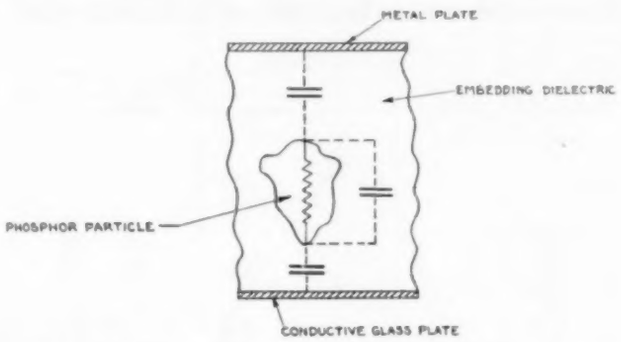

FIG. 4. Approximate equivalent circuit of phosphor particle embedded in dielectric medium between conductive plates at low frequency and fixed voltage. With the usual concentrations of phosphor particles and the usual ratios of the phosphor conductivity to the dielectric constant of the embedding medium, the series capacity is more important than the shunt capacity at low frequencies, and the voltage across the active part of the crystal is approximately in phase with the current through the device.

The resistance of the depletion layer will be higher than that of the interior of the phosphor and will, accordingly, be the main component of the phosphor resistance. The measured resistivity of phosphors of the type used in obtaining the Jerome (19) curves is between 10^9 and 10^8 ohm-cm, and, for a dielectric constant of about 8 in the embedding medium at 60 cps, the corresponding reactance of a unit element in the embedding material is 4×10^9 ohm-cm, which is sufficiently higher than the phosphor resistivity to give a rough justification for taking the series capacity as the main impedance at low frequency in the schematic diagram of Fig. 4. The diagram is limited to phosphor concentrations large enough to avoid the passage of much current directly through the dielectric from one lamp electrode to the other, but small enough to prevent much interaction between separate particles. This condition would seem

to be approximately fulfilled for the usual concentrations in the neighborhood of 30 per cent.

On this basis, the current curve in Jerome's oscillograms (19) can be taken roughly as giving the phase of the voltage across the phosphor particles, as indicated in Fig. 5. It is then clear that the minor peaks, which we have taken as due to excited but un-ionized centers whose emission is peaked in the blue, occur when the voltage is rising, and the major peaks, taken as due to ionized centers whose emission is peaked in the green, when the voltage is falling, the latter being in agreement with Waymouth and Bitter's (17) results for green-emitting phosphors. For yellow-emitting phosphors, the Waymouth-Bitter results showed most of the light emitted at the end of the cycle, as with the green phosphors, but about 25 per cent also occurred at the beginning of the cycle, as it would if some centers were excited only to intermediate nonionized states.

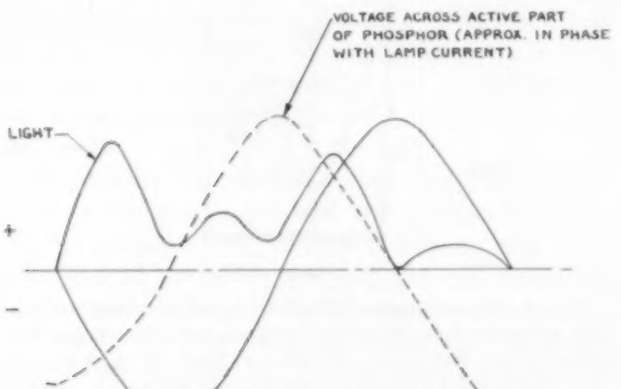

FIG. 5. Lamp voltage, lamp current (in phase with voltage across active part of phosphor), and light output vs. time.

This would indicate that some of the yellow centers were excited by transfer of energy from the normally green-emitting centers, and others were either excited directly or from the normally blue-emitting centers.

Waymouth and Bitter (9) have also shown that when a single luminous spot on the crystal is observed, it lights up only during one-half the cycle, as assumed in the foregoing. This would correspond to some of the asymmetrical crystal arrangements of Fig. 2. For example, if a high field existed at a sharp point under a depletion layer on the crystal, the excitation would be a one-way occurrence because the electrons could travel across the depletion layer from the inside semiconducting portion of the crystal, but there would be no source of electrons for the other direction. Excitation or ionization of centers would occur only on the side of the crystal which was positive.

Fig. 5, in which the dotted curve represents the voltage across the active part of the crystal (which is out of phase with the voltage across the lamp) shows that to be the case. The minor peak, which is presumably due to centers which are excited but not ionized, occurs as the voltage rises, and the major peak, due to recombination of electrons with ionized centers, occurs as the voltage drops. If the half-cycle during which these two events occur is taken as positive across the active part of the particle, then the major peak occurs during the first part of the positive half-cycle *of the lamp voltage*, just as Waymouth and Bitter (9) found for a single luminous spot. On the other hand, the luminescence from the short decay time or un-ionized centers occurs during the time that the voltage across the lamp is negative, and would agree with Zalm's results (18) if his activator centers were of the un-ionized type. On this basis, the Waymouth-Bitter (9) results are consistent with Zalm's (18), and with the step-function excitation (17).

Energy Levels of the Phosphor

It has been shown in the preceding section that the color shift with frequency in certain green-blue phosphors can be accounted for by the blue emission's occurring from the quick decay of ordinary states below the conduction bands, and the green emission's occurring either from the slower decay of electrons falling from metastable states or from distant positions in the conduction band. Waymouth and Bitter's (17) experiments, showing that the green emission ordinarily occurred on removal of the field, indicated that the electrons from the green-emitting centers went all the way to the conduction band and were carried away by the field, returning for recombination when the field was removed. There is also a further indication that in the green centers the electron goes to the conduction band.

Waymouth, Jerome, and Gungle (16) have shown that ZnS:Cu, Pb phosphors have emission bands centered at 2.70, 2.40, and 2.15 ev, corresponding to the blue, green, and yellow, respectively. Absorption bands, on the other hand, were found at 3.18, 2.70, and 1.0 ev, in addition, of course, to the fundamental band of about 3.5 ev. The absorption band at 3.18 ev was found much weaker in the blue phosphors, which contain less copper.

Thus, the blue centers appear to absorb at 2.70 ev and to emit at the same wave length, exactly as they would do if they were merely excited to the 2.70 level and returned directly from it with emission of scattered blue light. Since the blue emission has a quick decay, the level is not metastable.

In the green phosphor, however, no definite

absorption band at 2.40 ev, corresponding to the green energy, was reported. Instead, a definite band was found at 3.18 ev. This indicates that the green centers are excited to a 3.18 ev level, from which they drop back to a 2.40 level, and then from that level drop back to normal with emission of green light.

Since the conduction band is only about 3.5 ev above the valence band, and the ground level of the activator center is above the valence band, excitation of the activator center to the 3.18 ev level would seem to mean exciting it to the conduction band, as shown in Fig. 6. The excitation to the conducting levels can be due to the 2.40 ev level being just above the $3d^9 4s^2$ metastable state, as suggested by Butler (21). The electron is first excited to the metastable level, in which it remains until impact with another electron raises it to the conduction band, and it is carried away by the field. Or the excitation to the conducting band can be simply due to most of the free electrons having energies above 3.18 ev.

On removal of the field, the electron recombines with an excited center, where it is first caught in the 2.40 ev level, because that excited level has a much greater diameter for recapture of the electron (8) than the ground level, and then drops back to normal with emission of green light.

The absorption band below 1.0 ev could be due to lead atoms substituting for zinc or sulfur, losing or gaining electrons in the process, and becoming donor or acceptor centers of low energy. It could also be due to lead sulfide, which has an energy gap of between 0.5 and 1.0 ev. The absorption in this region could be due, however, to a still different reason.

The metastable state is the $3d^9 4s^2$ configuration, which is a configuration in which copper has two valence electrons. Just above the 2.40 ev levels there is the $3d^9 4s4p$ state (21), which in the crystal is probably depressed fairly close to the 2.40 ev level. The $3d^9 4s4p$ configuration not only has two valence electrons, but has them unpaired, which means that they are both available for covalent bonding. If the activation energy necessary to shift the atom to that state is supplied during the firing, the atoms may be permanently present in the crystal in that state. The lead compound added to the phosphor before firing may be what supplies the required activation energy, because the magnitude of the absorption at 1.0 ev is dependent on the lead concentration (16), at least up to the point where free lead sulfide appears to precipitate out as a separate phase.

Thus a certain amount of the copper could be present in the divalent $3d^9 4s4p$ state, and would presumably form CuS. Some free CuS can be removed (13), but presumably only that near the surface. The CuS bonds could be assumed to increase the conductivity of the phosphor, either by providing electrons from the CuS as a separate phase (12), or by exciting electrons from the Cu $3d^9 4s4p$ level to the conduction band thermally or by the field. The 1 ev activation energy required to free an electron in that case would insure that the resistivity be extremely high, as it is actually found to be.

Waymouth and Bitter (17) have found that the fields used in the present low-voltage phosphors can apparently free electrons from traps which would otherwise require radiation of wave lengths corresponding to about 1 ev, so that the fields present are sufficient to free such electrons from donor centers requiring 1 ev activation energy even when the field is not sufficient for tunnelling across higher energy gaps. Some electrons may also be

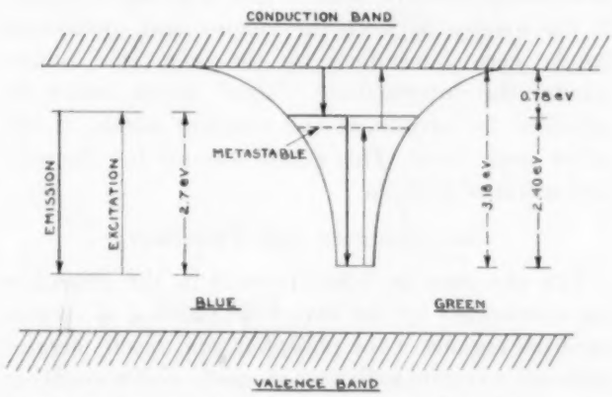

FIG. 6. Energy diagram of an electroluminescent zinc sulfide phosphor.

freed thermally from such donor centers or those of smaller activation energy.

It is interesting to note that although the presence of lead or some similar substance is necessary for good electroluminescence in the ZnS:Cu, Pb phosphors described by Butler (12), the brightness is not directly dependent on the exact amount of retained lead. This can be due to the lead's action being chiefly in increasing the conductivity of the phosphor, because once the conductivity of the main portion of the phosphor reaches a sufficient value, further increases will not greatly affect the voltage drop across the "barrier" or higher-resistance portion of the phosphor.

In the foregoing, it has been assumed, in agreement with Butler (21), that the copper is in the neutral state. This means that the activating copper is either interstitial or in a covalent form. The latter would seem to be indicated by the necessity for chlorine or some other coactivator to make the copper effective as a green emitter. The Cu Cl

bond is largely covalent (22), and gives a zincblende structure (23).

In ZnS, the purely ionic bond requires the Zn^{2+} and S^{2-} states, and the covalent bond requires the Zn^{2-} and S^{2+} states. These are the extreme states, and presumably some of the resulting intermediate covalent bonds will be such that the Cu Cl combination can be fitted into them. There will probably be only a few points at which this can be done, however, accounting for the rather limited solubility.

There must also be points where the copper atom or ion can be fitted into the lattice of itself, without benefit of chlorine, since Froelich's (24) red-emitting phosphor is actually free from coactivators. The blue band in such phosphors appears to be the same as in the chloride-containing phosphors, which would indicate that chlorine is not essential to the development of the blue-emitting centers. Since the blue band appears chiefly at low copper concentrations, it would seem to be due to zinc or sulfur. If the spacing between the valence and conduction bands were determined by the ionic zinc sulfide bonds, the intermediate "blue" levels could be provided by certain of the covalent bonds, if the latter were fewer. This could account for the self-activation of ZnS:Zn.

Efficiency of the Phosphor

The electrons or holes present in the phosphor are accelerated by the high field existing in certain localized regions of the phosphor, and reach energies sufficient to excite activator atoms to visible emitting levels. If the copper is present to the extent of about 0.0008 gram-atoms for each mole of zinc sulfide, there will be 8 copper atoms for each 10,000 atoms of zinc and 10,000 atoms of sulfur, that is, for each 20,000 atoms total.

That means, other things being equal, that for each useful collision at, say, 2.5 ev with a copper atom, there will be 2500 collisions with lattice atoms which will simply produce phonons, or lattice vibration energy. Mott and Gurney (8) state that each lattice collision produces only one phonon, and the average phonon energy appears to be about 0.04 ev. There will thus be 2500 × 0.04 ev, or 100 ev lost in phonons for every activator collision which produces a 2.5 ev photon for luminescence.

The efficiency on this rough basis would be 2.5/100, or 2.5 per cent. This checks very closely with measured values which indicate an efficiency of somewhat more than 2 per cent. For example, Butler, Waymouth, and Jerome (25) report an optimum efficiency of 4.24 lpw for a green-emitting electroluminescent lamp with a metallic backing electrode, and indications are that the efficiency would be 6.8 lpw (somewhat above 2%) with the metal layer replaced by a transparent conduction layer, and the total light output measured from both sides. Subtracting the dielectric losses in the material around the phosphor would make the actual phosphor efficiency somewhat higher.

The closeness of the check between calculated and measured efficiencies is partly fortuitous, however, because the calculated value was not corrected for the proportion of the accelerated electrons which actually reach excitation voltages before hitting an activator, nor for the probable differences in cross sections between the main lattice atoms and the activator atoms. These may compensate each other to some extent, but there would still be an additional loss in the nonluminescent portion of the phosphor. It may be that the copper activator concentration is greater near the surface, which would make it greater in the active region of the phosphor, and make higher efficiencies possible, or it may be that some of the main lattice atoms are excited and pass their energy along to the activator, thereby increasing the probability of excitation.

Acknowledgments

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Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the Journal.

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Rate of Displacement of Silver from Aqueous Silver Nitrate by Zinc and Copper[1]

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ABSTRACT

Displacement rates were measured by rotating cylinders of zinc and copper in silver nitrate solutions for short time intervals, followed by analysis of the solutions for silver ion content. At concentrations of a few hundredths molar silver nitrate, the rates are several times as great as calculated for normal diffusion or transport control, because of local cell electrolytic currents. This is analogous to previous results with similar systems. To minimize silver deposition and local cell action, very low silver ion concentrations ($2.5 \times 10^{-5}M$, $2.5 \times 10^{-6}M$) were also used, with radioactive Ag^{110} as tracer for the analysis. In these solutions the rates approach values calculated for normal transport control.

INTRODUCTION

Only a few quantitative measurements have been made of the rate of displacement of metal ions by more active metals using the rotating cylinder method or a similar technique. King and Burger (1) extended the measurements of Centnerszwer and Heller (2) on the displacement of copper from solutions of its sulfate by zinc and cadmium. The rates were approximately first order during a single run when the copper deposit was subjected to a mild scraping procedure. The displacement took place 5 to 7 times as fast as calculated for normal transport of copper ion to the surface by convection and diffusion, in spite of the tendency of the copper to cover and block the surface. This was explained as caused by local electrolysis between the active metals and the deposited copper. Since alloys are formed (3, 4), the electrolysis is complicated.

The purpose of the present investigation was to study this type of heterogeneous reaction in more detail, with wider variation in the factors which affect the rate. In particular, by using silver nitrate with radioactive Ag^{110} as tracer, it was possible to use solutions as dilute as $2.5 \times 10^{-6}M$, measuring the rate with a minimum of silver deposition. Zinc and copper were chosen for the displacing metals because of the considerable difference in their reducing potentials:

$$Zn + 2Ag^{+} \rightarrow Zn^{++} + 2Ag \qquad E^0 = 1.56 \text{ v}$$

$$Cu + 2Ag^{+} \rightarrow Cu^{++} + 2Ag \qquad E^0 = 0.45 \text{ v}$$

It was expected that local electrolysis and hence the over-all rate would be greatly influenced by the magnitude of these potentials, but actually this was not the case.

EXPERIMENTAL

Cylinders of C.P. zinc and electrolytic copper, 2.5 cm long and 1.8–1.7 cm in diameter, were rotated in the solutions as in previous work (1). The cylinders were polished with fine emery paper before each run, and rates were measured by titrating 25-ml portions of the original and final solutions with standard potassium bromide, with Rhodamine 6G as indicator. All runs were at 25° ± 0.2°C except in measuring temperature coefficients.

At first an attempt was made to extend the runs, with zinc, until most of the silver ion was removed from solution, withdrawing samples from time to time for analysis. The rate of silver loss was roughly proportional to the concentration, but was erratic in single runs or in duplicate experiments; no simple scraping technique was of assistance. It was noticed that initial rates were more concordant, and runs were continued, employing 400 ml of silver nitrate solution and a 2-min time of immersion, which resulted in 2 to 20 per cent decrease in silver ion concentration. With the dilute radioactive solutions, the volume was reduced to 300 ml and the time of each run was increased to 5 min, to secure a satisfactory decrease in the count from solution samples.

The silver deposited on both zinc and copper in black, spongy form. Some of it became detached from the zinc during 2-min runs, especially at higher concentrations and rotational speeds; the deposit on copper was more adherent. The most dilute solution ($2.5 \times 10^{-6}M$) gave a visible deposit on both metals in less than 5 min.

Duplicate runs at ordinary concentrations sometimes varied as much as 10 per cent, usually not more than 5 per cent. At the lowest tracer concen-

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tration, some runs varied as much as 25 per cent, mainly because the solution count was little more than twice the background count; in this case three or more results were obtained and averaged. If any result were questionable, as when two curves crossed on a graph, this feature was checked thoroughly. Average values in terms of micro-equivalents of silver lost from solution per cm^2 per min are reported. These are not instantaneous rates, but are probably the most comparable values obtainable from the data. The rate must actually vary a great deal when the cylinders are first immersed (very rapid initially, falling as a concentration gradient develops, increasing as local electrolysis starts), but it is believed that more or less of a "steady state" is rapidly attained.

To prepare the very dilute tracer solutions, a standard solution was first made by direct weighing

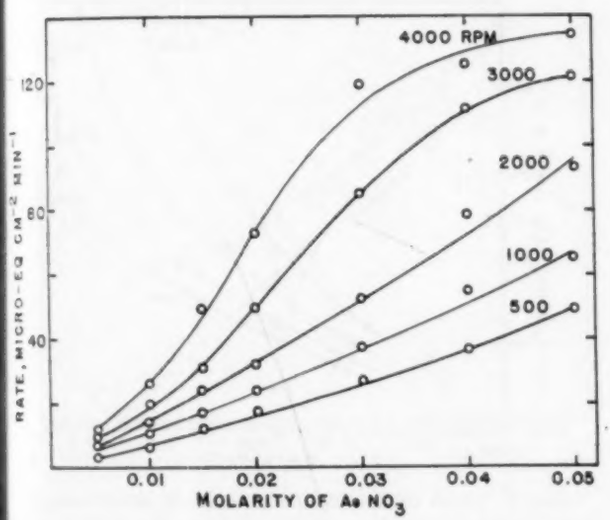

FIG. 1. Rate of displacement of silver by rotating zinc cylinders, 1.7—1.8 cm in diameter, at 25°C. Peripheral speed = rpm × 5.5.

of irradiated silver nitrate from the Oak Ridge National Laboratory. Aliquots withdrawn with suitable micropipettes were diluted quantitatively, and poured into a plastic beaker for use. For each analysis, three 2-ml portions, each in a small Petri dish, were counted using an end window GM tube. Tests showed no error from adsorption of silver ion on the walls of the vessels used.

All solutions were open to the air, and it was assumed, without checking, that the silver deposited was equivalent to the zinc and copper dissolved.

RESULTS

Displacement rates for zinc are plotted vs. silver nitrate concentration in Fig. 1. The rates are not strictly first order; they increase faster than the concentration, and, at higher rotational speeds, tend to approach maximum values.

Similar data for copper are shown in Fig. 2 by plotting rates vs. peripheral speed of the cylinder for various concentrations of silver nitrate. These rates are more nearly proportional to the concentration throughout, but show even greater tendency to approach maximum values at higher peripheral speed. Normal diffusion (or transport) control requires that rates be linear with peripheral speed above about 5000 cm/min (5).

While the rates with zinc and copper are not exactly the same, they are not at all proportional to the emf of simple Zn-Ag, Cu-Ag cells. Below 5000 cm/min, zinc reacts faster than copper; at 10,000–15,000 cm/min the reverse is true, while at 20,000 cm/min the curves for some concentrations have crossed again.

Rates in the very dilute tracer solutions are of the order of 10^{-9} equivalents cm^{-2} min^{-1} and could not be shown in Fig. 1 and 2. While the first order equa-

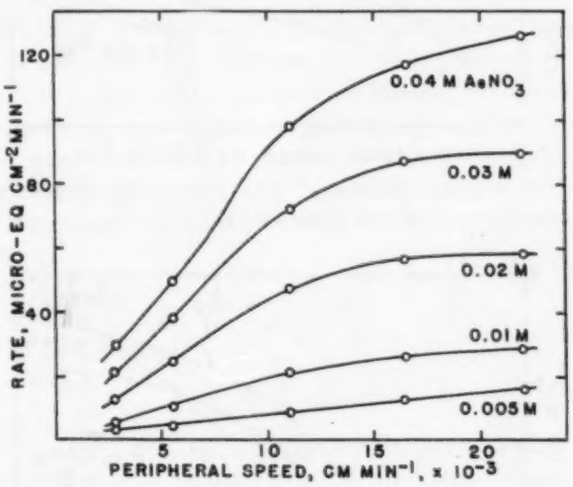

FIG. 2. Rate of displacement of silver by rotating copper cylinders, ~1.75 cm in diameter, at 25°C.

tion is not strictly obeyed, it is illuminating to compare values of the "rate constant" k calculated by means of the equation for first order heterogeneous reactions (1, 2):

$$k = \frac{2.3V}{At} \log \frac{c_o}{c} \qquad (I)$$

Here V = solution volume in cm^3, A = surface area in cm^2, c_o and c = concentrations at start and at time, t. This is equivalent to comparing rates divided by concentrations if the latter were sensibly constant during the runs.

Values of k are shown in Fig. 3 and 4 vs. peripheral speed. In general, k diminishes with decreasing concentration; however, curves for $0.04M$ and $0.05M$ would cross the others at about 16,000 cm/min if plotted in Fig. 3, and the curve for $0.005M$ crosses others in Fig. 4 (these results were verified by numerous check runs, as mentioned before). The low-

est values for zinc approach agreement with normal diffusion rate theory, as shown below.

Effect of inert salt.—In a diffusion-controlled reaction, nonreactive salts change the rates if they affect the diffusion coefficient of the critical reagent. The effect is mostly that of changing the viscosity of the medium (6). With electrochemical control, the rate depends on the conductance of the solution, and should be increased by a salt. Table I shows the

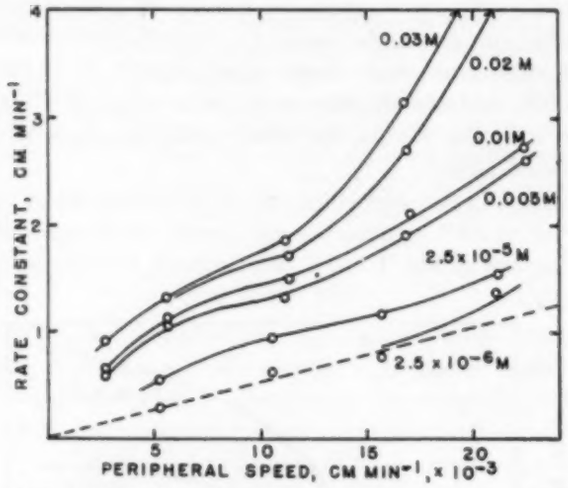

FIG. 3. Rate "constants" k for zinc cylinders, at 25°C. Dashed line represents equation (IV).

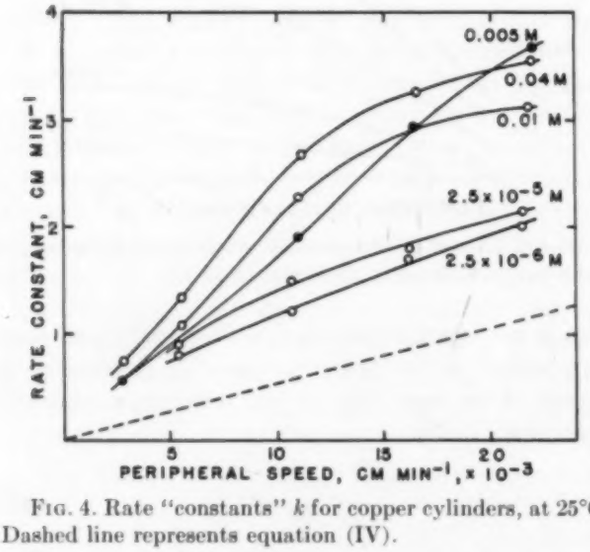

FIG. 4. Rate "constants" k for copper cylinders, at 25°C. Dashed line represents equation (IV).

effect of adding 1M sodium nitrate to 0.02M silver nitrate, on the zinc and copper displacement reactions. The relative viscosity of 1M $NaNO_3$ is 1.066, and this would retard diffusion somewhat.

Effect of viscosity.—To increase the viscosity of the solutions, sucrose was added in the concentrations 0.03M, 0.6M, and 0.9M. Rate measurements with zinc are shown in Fig. 5; results with copper were similar except for details. The effect is not as simple as that of decreasing the conductance of the solution or the diffusion coefficient of $AgNO_3$; either would require the rate to be linear with η_0/η at a given rotational speed.

Temperature coefficients.—Rates were measured in 0.02M $AgNO_3$ at temperatures from 5° to 45°C, as shown in Table II. The temperatures were carefully adjusted and did not change more than 0.2° during the 2-min runs.

TABLE I. *Effect of 1M $NaNO_3$ on the displacement rates at 25°C*

Zn and Cu cylinders 1.7 cm in diameter, 0.02M $AgNO_3$. Rates in micro-eq cm^{-2} min^{-1}.

	Zinc		Copper	
RPM	$AgNO_3$ alone	$NaNO_3$ added	$AgNO_3$ alone	$NaNO_3$ added
1000	25	34	25	31
2000	32	63	47	58
3000	49	77	56	62
4000	73	97	58	78

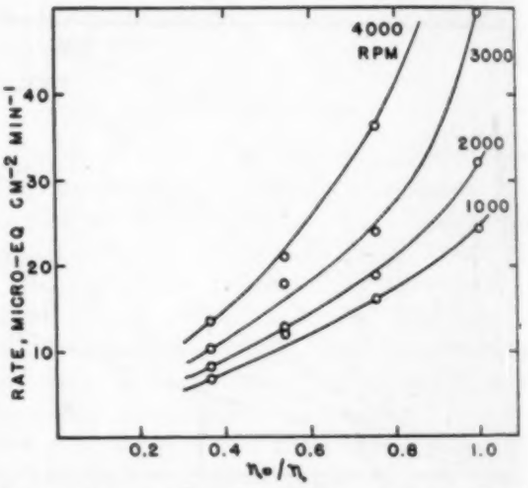

FIG. 5. Effect of increased viscosity on rate of displacement of silver from 0.02M $AgNO_3$ by rotating zinc cylinder at 25°C. Peripheral speed = rpm × 5.5.

TABLE II. *Temperature effect on displacement rates in 0.02M $AgNO_3$*

Cylinders approx. 1.7 cm in diameter. Rates in micro-eq cm^{-2} min^{-1}.

Temp, °C	2000 RPM		4000 RPM	
	Zn	Cu	Zn	Cu
5	13.6	11.4	19.4	13.4
15	19.3	27	32	30
25	31	47	73	58
35	33	63	92	88
45	35	79	95	115

Table II shows clearly what was noted before at 25°C: at intermediate rotational speeds, copper reacts faster than zinc, while at higher speeds the reverse is true. The temperature coefficient changes

markedly with temperature, averaging about 1.3 per 10° in the range 25°–45°C, rising to about 2 at lower temperatures. Calculated activation energies then range from 2000 to 12,000 cal/equiv., but have little quantitative significance since the rates are complex, as discussed below.

External polarization of the copper.—Sometimes information can be gained about the nature of an electrochemical surface process by imposing external potentials on the test specimens. If local anodes and cathodes can be polarized to the same potential, action must cease if it is solely the result of local cell electrolysis. Or it may be possible to change the potential of a metal with respect to solution so that it is thermodynamically inactive—in a "domain of passivity"—with respect to a particular reaction (7). For example, if copper could be brought to the

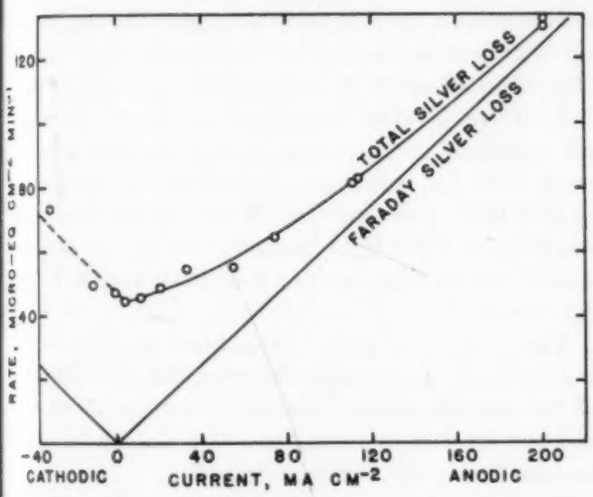

FIG. 6. Effect of imposed potentials on rate of displacement of silver by copper cylinder rotating at 2000 rpm (peripheral speed 11000 cm/min) in 400 ml of 0.02*M* $AgNO_3$, at 25°C.

cathodic potential of silver, no displacement could occur. This could, in practice, be done only by passing current to maintain the desired potential, and is equivalent to saying that, if displacement occurred, the copper ions formed would immediately be redeposited. The net effect would be faradaic deposition of silver with no additional displacement.

Fig. 6 shows the results of imposing anodic and cathodic potentials on a copper cylinder at 2000 rpm in 0.02*M* $AgNO_3$, with a platinum sheet 8 x 12 cm as second electrode. Current was measured with suitable meters and used to calculate the "Faraday loss" lines; quantitative silver deposition by the current on whichever electrode was cathode was assumed, since there was no visual evidence of hydrogen evolution. The dashed line is drawn parallel to the cathodic Faraday line.

There is evidently no "cathodic protection" over the small range of current density employed. At the higher anodic current densities (on copper) the silver ion concentration decreases considerably during 2-min runs; at 200 ma/cm², the loss is nearly 50 per cent. Nevertheless, it is evident that local displacement is diminished somewhat. Larger currents could not be passed without heating the solution too much, but when over 100 v was applied to the rotating cylinder and the latter was immersed momentarily, a visible deposit formed on the copper. It is believed that this consisted of displaced silver, not anodically deposited oxide.

Discussion

The rates to be expected for a normal transport-controlled process with the rotating cylinder technique employed here can be calculated with satisfactory approximation by means of the equation (8)

$$dn/dt = 0.010\, A\, v\, c\, (D/\nu)^{0.83} \qquad \text{(II)}$$

Here dn/dt = equivalents transported per unit time, A = surface area, v = peripheral velocity of cylinder, c = concentration (assumed to fall to zero at the surface), D = diffusion coefficient of reagent, ν = kinematic viscosity of solution (viscosity η divided by density).

By comparing with the differential form of equation (I)

$$dn/dt = kAc \qquad \text{(III)}$$

it is seen that

$$k = 0.010\, v(D/\nu)^{0.83} \qquad \text{(IV)}$$

Using $D = 1.6 \times 10^{-5}$ cm²/sec for dilute silver nitrate (9) and $\nu = 9 \times 10^{-3}$ cm²/sec for dilute aqueous solutions at 25°C, k has been calculated (in cm/min) and appears as the dashed lines in Fig. 3 and 4.[2]

Most of the rates are then considerably greater than can be accounted for by normal convective and diffusive transport. Another way of expressing this fact is to calculate values of the "effective diffusion layer thickness," which are then smaller than normal (1). Factors such as increase in effective area because of the silver deposit, or surface roughness which would increase turbulence in the adjacent solution, are quite inadequate to account for the greatly enhanced rates.

It is concluded that a concentration gradient does exist at the surface of the cylinder (or the silver deposit), and that the effective thickness is kept abnormally small by local cell electrolysis. It is well known that electrolytic current streamlines extend

[2] In deriving equation (II) it was assumed that dn/dt (or k) is linear with v down to $v = 0$. This is not quite true (5, 6) with cylinders and solution vessels as customarily used.

for some distance outside the volume between a pair of electrodes; and that a potential gradient extends for some distance into a salt solution away from the junction of a pair of dissimilar metals (10).

The thickness of the diffusion layer is normally determined by a balance between the hydrodynamical nature of convection and the diffusivity of the reagent. If potential differences exist at the metal surface and in the adjacent solution, silver ions will be forced to cathodic areas faster than the rate of natural diffusion. The depletion will cause readjustment of the entire layer to a new steady state.

At the steady state, the rate might be expressed either in terms of diffusion, as by equation (III) with $k = D/\delta$, where δ is the "effective thickness," or in terms of the rate of the electrochemical process, which must be equal in magnitude. One might hope to apply an equation of the type first developed by Palmaer (11):

$$dn/dt = k' e \kappa/a \qquad (V)$$

where k' is a constant, e is the emf of the local cells, κ is the specific conductance of the solution, and a is a value depending mainly on the anodic and cathodic areas (the "resistance capacity" of the local cells).

Equation (V) cannot be applied quantitatively, because the effective values of the terms are unknown. It is true that the rate depends on κ (Table I), but it is by no means directly proportional to this value; equation (V) would not require linear dependence, since e and a might be altered by the experiment. Further, any change in the electrochemical process is not complete in itself, but must lead to a new value of δ in the diffusion equation.

Besides, e is most likely not a simple or single emf for pure Zn-Ag or Cu-Ag couples. According to Straumanis and Fang (4), dissolved zinc ion appears to redeposit on silver in small amounts, perhaps in thin layers, without forming solid solutions rich in zinc. Copper and silver have not been investigated in the same manner. However, the authors have prepared crystalline silver by reduction of silver nitrate with copper as described by Walden, Hammett, and Edmonds (11), and after thorough washing have dissolved samples in nitric acid and tested for copper; no more than traces were found.

From the displacement rates found it is concluded that for the most part the effective emf is nearly the same in both cases, or that the actual value is not very important in readjustment of the concentration gradient. The tracer experiments with copper show that surface electrolysis is still important with the very small amount of silver deposition; the lower rates with zinc indicate either that the effective emf is small, or that reduction of anodic area by the deposit diminishes the electrolytic current enough to bring the rates, by coincidence, near those of normal diffusion control.

It becomes apparent that more comparable rates might be obtained, not by employing equal time intervals for the runs, but by measuring times of equal silver deposition. The more quickly silver deposits, the greater the local electrolysis; the process is "autocatalytic." After enough time, the process chokes itself; the deposit is not as porous, the anodic and cathodic areas approach a steady condition, and increased concentration or rotational speed have less effect.

These factors must account for the peculiarities of Fig. 3 and 4, including the crossover of curves for 0.04 and 0.05M silver nitrate if plotted in Fig. 3 and of the curve for 0.005M in Fig. 4. Values of k or of average silver deposition per minute divided by concentration, at low peripheral speeds, rise steadily with concentration for both zinc and copper. The effect of silver deposition during 2-min runs is still increasing with concentration. But at the highest rotational speed, values of k go through a maximum with concentration. With zinc, the maximum is at 0.03M silver nitrate. With copper, the maximum is at 0.005M or possibly below this concentration where data are not available, and is 25 per cent lower than for zinc.

These effects cannot be explained quantitatively, but indicate the relation between the effective emf of the metallic couples, the relative amounts of area blocked by the deposits, and the change of these factors during the two-minute runs.

The same factors no doubt account for the abnormally large effect of increasing the viscosity, as compared to the usual diffusion-controlled reaction. Primarily the rates of both diffusion and electrolysis are reduced. But since this diminishes the amount of silver deposited in a given time, the amount of electrolysis is further restricted and the net effect is an abnormally large viscosity effect, as shown in Fig. 5. The rate is affected in roughly the same way for both metals, but curves for zinc, if plotted vs. rotational speed, are concave upward; similar curves for copper show decreasing slopes, with little change in rate from 3000 to 4000 rpm.

The changing temperature coefficients can be explained on a similar basis. Any factor which increases the displacement rates will have a greater effect, in terms of per cent, on low rates than on high rates, since the first silver deposited has more effect than additional amounts. The greater decrease in viscosity, per degree, at low temperatures, leads to a greater increase in diffusion, electrolysis, and silver deposition, and this in turn to a still greater increase in rate. At higher temperatures, the larger amount

of silver deposition in a given time leads to a smaller percentage increase with rising temperature.

While there are certain differences between the results with zinc and copper as noted above, the rates are actually not greatly different and are remarkably similar to the rates found previously for the displacement of copper from copper sulfate by zinc and cadmium (1) at the same rotational speeds. It would be extremely useful to know more about the effective emf of the metallic couples formed and its influence in the displacement process.

Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the JOURNAL.

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Technical Note

The Measurement of Quantum Efficiency of Fluorescent Lamp Phosphors[1]

CHARLES W. JEROME

Sylvania Electric Products Inc., Salem, Massachusetts

Some recent measurements have been made on the quantum efficiency of fluorescent lamp phosphors by the method employed by Thayer and Barnes (1). This method consists of comparing the photometered luminous efficiency (lpw) of a lamp to its calculated lpw, assuming 100 per cent quantum efficiency for the powder.

This method has not been widely used, possibly due to lack of understanding of its derivation. Most measurements appearing in the literature are made by irradiating a sample of the powder with a known amount of 253.7 mμ radiation and measuring the amount of radiation emitted by the phosphor (2). This measurement is complicated by the difficulty in measuring the absolute quantity of actinic radiation, and recourse is usually made to assumptions as to the efficiency of some powder chosen as a standard (usually magnesium tungstate = 100%) and the performance of other phosphors compared thereto.

The method used in the present measurements obviates the recourse to a reference standard, and direct comparisons can be made between measurements separated by considerable periods of time. Also, since the measurements are made on the phosphor in its final form as incorporated into the lamp, they furnish information of more interest to the lamp manufacturer.

The basic formula for the luminous efficiency of a lamp with 100 per cent quantum efficiency for the phosphor is:

$$\text{lpw} = F\,\frac{A\int E_\lambda \bar{y}\, d\lambda}{B\int E_\lambda \frac{\lambda}{253.7}\, d\lambda} + C \qquad \text{(I)}$$

where: E_λ = spectral energy distribution (SED) of the phosphor emission; $\bar{y}$ = C.I.E. luminosity function; A = conversion factor to give the numerator integral in lumens; B = conversion factor to give the denominator integral in total watts input to the lamp; C = contribution of the mercury arc to the luminous efficiency of the lamp; and F = factor to correct for loss of actinic radiation and emitted light at the ends of the lamp and absorption of light by the phosphor and glass bulb.

The theoretical maximum lpw possible for any source is 680 lpw (3). This would be obtained if all the energy input were emitted as 555 mμ radiation to which the eye is most sensitive. Due to the loss of energy in the quantum conversion and since only a fraction of the input power appears as 253.7 mμ radiation (55% assumed for the present purpose), the theoretical maximum lpw for a fluorescent lamp is 171 lpw [680 × 0.55 × (253.7/555)]. This would be obtained if 55 per cent of the input power appears as 253.7 mμ, the quantum efficiency of the phosphor is 100 per cent, and the phosphor emission is monochromatic at 555 mμ. Substituting these conditions into the above equation with F = 1.0 and C = 0, the ratio, A/B, is found to be 374.

The contribution of the mercury arc to the luminous efficiency of the lamp, C, varies from lamp to lamp, depending primarily for any given size on the density of the phosphor coating on the bulb. It can be determined by the relative contribution to the total light output of the arc and phosphor which can be determined from the SED curve (4). The average for a number of 40T12 lamps by this method has been determined as approximately 5 lpw.

The factor, F, has been investigated by Thayer (5). He arrived at a combined factor of 77 per cent, for a 40-watt lamp, based on data obtained for experimental lamps of highest possible efficiency. In a separate investigation in this laboratory, 75 per cent was derived as being more representative of most lamps.

Therefore, for 40-watt lamps, equation (I) becomes:

$$\text{lpw} = 281\,\frac{\int E_\lambda \bar{y}\, d\lambda}{\int E_\lambda \lambda/253.7\, d\lambda} + 5.0 \qquad \text{(II)}$$

[1] Manuscript received February 2, 1953. This paper was prepared for delivery before the New York Meeting, April 12 to 16, 1953.

In Table I are given results of measurements by the above method on several "white" 40T12 fluorescent lamps. The values in columns (*A*) and (*B*) were obtained by summing up the indicated products at 20 mμ intervals. Since the performance of the phosphor is the primary interest in these measurements, the theoretical lpw's given in column (*C*) are derived by equation (II) without the addition of the mercury arc (constant *C*). Similarly, the observed lpw's given in column (*D*) are the photometered values minus the 5 lpw due to the mercury arc. In the last column of the table are given the quantum efficiencies of the unmilled powders used in these lamps as determined by the conventional method using magnesium tungstate as a reference standard.

TABLE I. *Quantum efficiencies (QE) of phosphors in 40T12 lamps**

Phosphor	(*A*) $\Sigma E_\lambda \lambda/253.7$	(*B*) $\Sigma E_\lambda \bar{y}$	(*C*) Theor. lpw (phos)	(*D*) Obs. lpw −5	(*E*) QE (*D*) ÷ (*C*)	(*F*) QE (conv.)
Magnesium tungstate	669.9	126.0	52.8	44.2	84%	100%
Daylight†	571.8	117.3	57.6	54.3	94	94
Std. cool white†	621.5	144.4	65.2	59.9	92	90
White†	603.9	138.8	64.5	58.8	91	89
Std. warm white†	572.3	140.1	68.7	58.7	86	94
Soft white‡	520.5	102.3	55.1	46.4	84	81
Cool white deluxe‡	550.9	108.0	55.0	45.0	82	92
Warm white deluxe‡	493.7	99.7	56.7	46.8	83	84

* Zero hour lamps.
† Calcium halophosphates.
‡ Blends of calcium silicate (Mn,Pb), magnesium tungstate, and zinc orthosilicate (Mn).

The poor showing for magnesium tungstate (column *E*) is attributed to deterioration of the phosphor during the processing of the lamp. This phosphor is known to be quite heat-sensitive, and, in the baking-out of the bulb coating and during the baking step of the pumping schedule, such deterioration is very probable. Similarly, it would seem that the standard warm white lamp used for the above measurement is below the average luminous efficiency of lamps of this color and type. It is a halophosphate like the other standard colors and should have a quantum efficiency in the range of 90 to 95 per cent. By the same reasoning, 92 per cent as the quantum efficiency by the conventional method for the cool white deluxe seems too high. It is the same type of blend of phosphors as the soft white and warm white deluxe and would be expected to have very nearly the same QE as those blends.

These discrepancies will have to be resolved by checking a much larger number of lamps and powders by the two methods. However, they serve to point out one of the major advantages of the present method. That is, a lamp manufacturer is primarily interested in the performance of phosphors in their final form as incorporated in the finished lamp. The theoretical lpw's (column *C*) furnish a goal to which he should aspire, and the quantum efficiency by the present method tells him how close he is to attaining the goal. Further, a comparison of quantum efficiencies by this and the conventional methods will give an indication whether the best line of attack for more efficient lamps is an improvement of lamp manufacturing procedures (indicated by a lower QE by the present method than obtained with the conventional method) or an improvement in the phosphor itself (indicated by approximately the same QE by the two methods).

In summary, there have been presented some measurements of the quantum efficiencies of present-day fluorescent lamp phosphors by a method which is particularly applicable for measurements of powders incorporated in fluorescent lamps. The derivation of the formula used has ignored any activation of the phosphor by any radiation other than 253.7 mμ. This introduces a slight variable error depending on the phosphor in question. However, with any given set of assumptions, this method gives convenient results which are comparable within themselves, and within which comparison can be made of results obtained at separate times without requiring the repeated measurement of a reference standard.

Any discussion of this paper will appear in a Discussion Section, to be published in the June 1954 issue of the JOURNAL.

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Discussion Section

ELECTRICAL MEASUREMENTS ON ELECTROLUMINESCENT LAMPS WITH ZINC SULFIDE PHOSPHORS

C. W. Jerome and W. C. Gungle (pp. 34–38)

SHEPARD ROBERTS[1]: Mr. Jerome described a method of extrapolating the curve of power factor vs. voltage of an electroluminescent lamp to zero volts. He attributed the limiting power factor, φ_0, to the dielectric alone. I suggest that he may not have taken proper consideration of the ohmic losses which occur in the phosphor itself even at low voltages. When these are considered it is not surprising that lamps of different geometry have strikingly different characteristics of φ_0 vs. frequency even though the same dielectric is used.

C. W. JEROME AND W. C. GUNGLE: Attributing the φ_0 derived to the dielectric alone is supported by the comparison of the two lamps with, and without, phosphor described in the paper. As described also, there is a non-ohmic component to the resistive part of the lamp impedance which is attributed to the phosphor. It is believed that this component decreases with the applied voltage and explains the curvature of the light output vs. phosphor watts in Fig. 7.

The suggested analogous circuits shown in Fig. 11 are not intended as the only ones which can be made to apply to this lamp. They are merely two circuits whose behavior is the same as the phenomena reported in this paper. As pointed out, the point for a minimum value of the power factor as a function of frequency can be varied simply by changing the values of the circuit elements. Since R_1 is the circuit element most directly responsible for the location of the minimum in the curves of Fig. 10, and this element represents the series resistance of the conducting coating of the glass, it is not surprising that various shapes and sizes of lamps have minima in different places. This resistance is affected by the shape and also by the location of the contact made to the conducting strip.

INFLUENCE OF IMPURITIES IN THE ELECTROLYTE IN CHLORINE-CAUSTIC ELECTROLYSIS BY THE MERCURY CELL PROCESS

III. Investigation of the Influence of Anions upon the Decomposition Rate of Sodium Amalgam

Gösta Angel, Tage Lundén, and Rolf Brännland (pp. 39–44)

MORRIS FEINLEIB[2]: Is it possible that the stannate will be reduced to tin, or to a tin alloy with a harmful metal (such as vanadium) by the sodium amalgam? As a result, the alloy could be wetted by mercury and thus not become a center of low hydrogen overvoltage and, consequently, hydrogen evolution. This would explain the inhibiting effect of the stannate.

GÖSTA ANGEL: I think the inhibiting effect of the stannate as well as of the silicate may be explained by the adsorbtion of the harmful impurities on the stannic or silicic acid when the acid is flocculated from a colloidal state. In the flocculated state, the stannic acid does not take any part in the electrolysis.

OPTICAL MEASUREMENTS ON ELECTROLUMINESCENT ZINC SULFIDE

John F. Waymouth (pp. 81–84)

SHEPARD ROBERTS[1]: The brightness of an electroluminescent lamp depends very critically on the dielectric constant of the dielectric medium. In view of this, would Mr. Jerome kindly tell how much the dielectric constant varied in the range of temperature studied, and what effect this had on the observed changes in brightness?

JOHN F. WAYMOUTH: In answer to Dr. Roberts' question, I regret that I can only say that I do not know what is the dependence on temperature of dielectric constant of the impregnating medium. For this reason, among others, mention of the temperature dependence of the brightness of electroluminesent lamps was omitted from the paper as it was published in the JOURNAL.

CATHODIC LEAD DISINTEGRATION AND HYDRIDE FORMATION

Hugh W. Salzberg (pp. 146–151)

G. DUBPERNELL[3]: Dr. Salzberg's excellent quantitative investigation is a welcome contribution. However, his proposal to explain this rather well-known phenomenon by means of lead hydride formation seems unnecessary and confusing in view of the existing satisfactory explanation which the writer has discussed in part elsewhere.[4] Hurd[5] indicates that rather little is known regarding the hydride of lead, and gives PbH_4 as the normal composition of plumbane instead of the PbH_2 suggested by Dr. Salzberg.

The disintegration of lead cathodes was observed by Reed[6] in 29 different solutions, but not in 14 others. Bredig and Haber[7] give a detailed review of early investigations extending back to 1808. Haber later[8] published the results of more comprehensive investigations.

This Discussion Section includes discussion of papers appearing in the JOURNAL OF THE ELECTROCHEMICAL SOCIETY, **100**, No. 1-6 (January-June 1953).

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[2] Division of Metallurgical Research, Kaiser Aluminum & Chemical Corporation, Spokane, Wash.

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[7] G. BREDIG AND F. HABER, *Ber.*, **31**, 2741 (1898).

[8] F. HABER, *Z. Elektrochem.*, **8**, 245, 541 (1902).

and also presented a shorter report to this society.[9] His student, Sack, published an even more extensive study.[10]

These investigations established that lead and other metals disintegrated in exactly the same fashion whether treated as cathode at high current density, or alloyed with a certain percentage of alkali metal and simply immersed in the solution without current. The cathodic formation of an alkali metal alloy affords a satisfactory explanation of the phenomenon, and the behavior in acid solutions is not inconsistent with this explanation. There is always sufficient alkali metal present in acids so that dilute solutions exhibit the phenomenon. Sufficient purification of the acid would probably eliminate the disintegration in dilute acid solutions.

HUGH W. SALZBERG: On reexamination of the evidence, I must continue to disagree with the alkali metal hypothesis of Bredig and Haber, for the following reasons.

1. The lead-alkali metal postulated by these authors would not be formed under the conditions of my experiments. The deposition potential of sodium from 1*N* NaOH is 2.7 volts. The cathode potentials of my experiments were of the order of 1 volt. No alkali metal would, therefore, be expected to deposit. In addition, cathode disintegration was observed in dilute acid solutions where any sodium ion would be present only as an impurity. If the sodium ion concentration were as great as $10^{-5}N$, the discrepancy between the sodium deposition potential and the actual cathode potential would be about 2 volts. No sodium ion would deposit under these conditions.

2. Even if such an alloy were actually formed, it could not be responsible for the disintegration of the lead cathode. (*a*) The observed disintegration rates were inversely proportional to the sodium ion concentration. The rates in $4 \times 10^{-2}N$ NaOH were more than twice as great as those in 4*N* NaOH. The disintegration would not, therefore, seem to involve sodium ion. (*b*) In solutions containing pure acid and no added alkali, as much as 1 millieq/cm² of lead left the surface per second. If the solution contained as much as 10^{-5} equivalents of NaOH per liter and the diffusion rate of sodium ion were as much as 10^{-2} cm/sec, the maximum amount of sodium ion that could be plated out would still be only about 10^{-2} millieq/sec, two orders of magnitude less than the observed disintegration rate. (*c*) The disintegration rate had a negative temperature coefficient, while the formation of an alloy and its solution would have a positive temperature coefficient.

3. Formation of a lead hydride is directly analogous to the formation of hydrides of antimony, arsenic, bismuth, silicon, germanium, tin, etc. Electrolytic formation of a volatile and unstable lead hydride, which would explain the cathodic disintegration, was observed by Paneth, who assigned the formula PbH_4 by analogy with the hydrides of silicon and carbon. No plumbane has ever been actually analyzed, to my knowledge, due to its instability. Incidentally, I now feel that the formula should be Pb_2H_4 instead of PbH_2.

4. The explanation of the behavior of a lead-alkali metal alloy immersed in solution is probably due to the formation of electrochemical couples. The potential difference between the lead and the sodium would be at least 2.5 volts or more than sufficient to form plumbane.

[9] F. HABER, *Trans. Am. Electrochem. Soc.*, **2**, 189 (1902).

[10] M. SACK, *Z. anorg. Chem.*, **34**, 286 (1903).

EFFECT OF GERMANIUM ON THE TRANSFORMATION OF WHITE TO GRAY TIN, AT COMPARATIVELY LOW TEMPERATURE

R. R. Rogers and J. F. Fydell (pp. 161–164)

L. J. GROEN[11]: Rogers and Fydell[12] describe the accelerating influence of germanium on the transition of white into gray tin. Such an influence was observed when germanium was alloyed with tin, or, as a metal, in direct contact with it, and, finally, when tin was immersed in a solution containing germanium ions.

For many years it has been well known that small amounts of strange metals may have an accelerating or retarding influence on this transition. It was Cohen and his collaborators[13, 14, 15], who, by their extensive research on this transition, worked out the effect of metals alloyed with tin in small quantities. It was shown that Co, Mn, Te, and especially Al, Mg, Zn (down to 0.01%) increase the rate of transition, while Sb, Pb, Cd, Ag, Au, and especially Bi (0.01%) decrease this rate. Part of those results are described by Tammann and Dreyer,[16] and were confirmed recently by Hedges and Higgs.[17]

In the case of an accelerating metal, the positive influence is supposed to be due to a deformation of the tin-lattice. That various types of deformation of pure tin cause a rapid transition was shown by Cohen[18] and later by Hedges and Higgs[17] and Ishikawa.[19] One can draw the conclusion that lattice deformation might also be the reason for the behavior of a tin-germanium alloy.

Also, the fact that tin ions in solution accelerate the transition was mentioned by Cohen.[20] Recent investigations in this laboratory, which will be published later, showed that already very small quantities of tin ions, independent of valency or complex form, had an accelerating influence. Even when white tin powder was treated with a 1 per cent HCl solution in alcohol at −50°C, the effect of the tin dissolved by hydrochloric acid during the treatment was very marked. In accordance with the results of Rogers and Fydell, Al and Zn ions did not have any influence on the transition. Moreover, Cohen[14] found

[11] Laboratory for Physical Chemistry, Technical University, Delft, Holland.

[12] R. R. ROGERS AND J. F. FYDELL, *J. Electrochem. Soc.*, **100**, 161 (1953).

[13] E. COHEN AND A. K. W. VAN LIESHOUT, *Z. physik. Chem.*, **A177**, 331 (1936).

[14] E. COHEN AND W. A. T. COHEN-DE MEESTER, *Proc. Roy. Soc. Amsterdam*, **41**, 462 (1938).

[15] E. COHEN AND W. A. T. COHEN-DE MEESTER, *Proc. Roy. Soc. Amsterdam*, **41**, 860 (1938).

[16] G. TAMANN AND K. L. DREYER, *Z. anorg. u. allgem. Chem.*, **199**, 97 (1931).

[17] E. S. HEDGES AND J. Y. HIGGS, *Nature*, **169**, 621 (1952).

[18] E. COHEN, W. A. T. COHEN-DE MEESTER, AND A. K. W. VAN LIESHOUT, *Z. physik. Chem.*, **A173**, 169 (1935).

[19] H. ISHIKAWA, *J. Phys. Soc. Japan*, **6**, 531 (1951).

[20] E. COHEN, *Z. physik. Chem.*, **A30**, 625 (1899).

that metallic aluminum in contact with pure tin had no effect on the rate of transition.

In Rogers and Fydell's experiments, germanium was brought in contact with tin in an *acid* solution, so either germanium or tin or both might dissolve and promote the transition at low temperatures. However, nothing can be deduced from their work about the influence of metallic germanium in contact with pure tin *without* the presence of a dissolving agent. Furthermore, on the basis of their experiments it seems doubtful whether the influence of metallic germanium can be compared to that of germanium alloyed with tin.

Why germanium deposited on or eventually in contact with pure tin causes inoculation cannot be explained with the present lattice deformation theory. Although germanium and gray tin have the same character in their physical properties, their lattice constants (respectively, 5.36 and 6.46 Å) differ to such extent that it seems difficult to assume a simple building up of gray tin around a particle of germanium.

R. R. Rogers and J. F. Fydell: It is true that work has been done on the gray tin transformation by a number of earlier workers. Erdmann published an article on the subject as early as 1851. However, as far as we are aware, nothing has been published on the effect of germanium, which is the subject of the present paper. The summary of published information on gray tin, referred to in our paper, includes a list of the publications and their authors. This summary is available on request.

We would like to point out an error in Mr. Groen's remarks. No mention was made of aluminum in our paper.

Bruce W. Gonser[21]: Have you tried using silicon to initiate transformation in place of germanium? My reason for mentioning silicon is the similarity in structure to germanium and gray tin, and the fact that all three metals are semiconductors.

Incidentally, one might well stress the difficulty in converting commercial tin into the gray form under normal conditions of usage. This possibility of tin conversion at low temperatures is so rarely encountered in practice that it is a factor of very minor importance. Commerical tin normally contains sufficient bismuth, antimony, or other constituents to inhibit the conversion. For a critical use at low temperatures, it is easy to assure stability by purposely adding small amounts of such inhibitors.

R. R. Rogers and J. F. Fydell: We have performed experiments with silicon, but so far we have been unsuccessful in bringing about inoculation by this means.

We agree that gray tin formation may be inhibited by the addition of small amounts of certain other metals. Data supporting this statement have been presented in our recent paper.[22]

[21] Battelle Memorial Institute, Columbus, Ohio.

[22] R. R. Rogers and J. F. Fydell, *J. Electrochem. Soc.*, **100**, 383 (1953).

THE CAUSTIC ELECTROLYTIC-ZINC PROCESS

Charles T. Baroch, R. V. Hilliard, and R. S. Lang

(pp. 165–172)

Harry J. Morgan[23]: The dissolution of zinc from oxidized ores by caustic soda solution and electrolytic recovery as dust, described in the U. S. Bureau of Mines paper, is very similar but in some respects differs from the process described by Morgan and Gray.[24]

The history of this development might be of interest. Morgan, while a Fellow of Metallurgical Research at the University of Utah, carried on research in 1915 to determine whether a method of producing zinc dust could be made to remedy the serious shortage caused by the capture of the Belgian Zinc Smelters by Germany. These smelters had been an important source of zinc dust used in the cyanidation of gold and silver ores. Atomization of molten zinc was tried, but the product, although finer than 200 mesh, had a low precipitating efficiency. Electrolysis of zincate solutions was attractive and seemed promising, since the dust made had a very high precipitating efficiency for gold and silver cyanide solutions, in fact, higher than most zinc dusts on the market. It was planned to use the oxidized zinc ores of Utah. A search of the literature showed that the basic features of the process were covered by a U. S. patent issued to Cowper-Coles.[25] Since it was difficult to interest capital in a process not protected by patent, nothing further was done at that time. The results of this work were published later by Morgan and Ralston.[26]

In 1940 shortly before World War II, the combination of power development at Hoover Dam and the proximity of considerable tonnage of oxidized zinc ores at Good Springs, Nevada, not amenable to economic treatment, suggested further development work. Morgan and Gray procured samples from more than a dozen mines and tailings piles, and completed laboratory experiments sufficiently successful to warrant the construction of a pilot plant. Negotiations for financing were halted due to the declaration of war and no further work was done until after the close of the war. In 1948, work was resumed, but financial backing was later withdrawn due to lack of patent protection and similar competitive work by the Bureau of Mines. The results of this work were published in 1950.[24]

The main difference from the Bureau of Mines process was that all the ore was given a preliminary calcination at 500° C which decomposed the zinc carbonate minerals. This not only minimized the buildup of carbonate in the solutions, but dehydrated the gangue, facilitating decantation and filtration. A short period of agitation with hot 25 per cent caustic solution gave over 90 per cent dissolution of the zinc content of most oxidized ores. The pulp was settled, the zincate solution decanted. After dilution of the thickened pulp, the remaining soluble values were recovered by filtration and these diluted wash solutions causticized with lime to remove silica and car-

[23] 2830 Broadway, Huntington Park, Calif.

[24] H. J. Morgan and J. C. Gray, *Eng. Mining J.*, **15**, 72 (1950).

[25] Cowper-Cowles, U. S. Pat. 923,411, June 1, 1909.

[26] H. J. Morgan and O. C. Ralston, *Trans. Am. Electrochem. Soc.*, **30**, 229 (1916).

bonate. This prevented the buildup of these impurities in the solution circuit. A better method of removal of carbonate without the use of lime was developed. Since there was no large precipitate of calcium carbonate to be washed, losses of soda were negligible. The use of zinc dust for the removal of lead and copper from the solutions was the same in both processes. The zincate solution was electrolyzed at 3.5–4 volts with a current density of 300 amp/ft², using a rotating drum cathode from which the zinc sponge was scraped somewhat like the cake from an Oliver filter. The zinc sponge was filtered and washed, care being taken not to dry too thoroughly, since partially dried dust is pyrophoric. The moist filter cake was placed in a vacuum drier which operated without difficulty. The power consumption was 2 kwhr/lb of zinc, but the increased power cost due to high current density was balanced by the smaller equipment necessary, and the heat generated was used in the process. The dust produced, instead of being coarse spangles, would all pass 200 mesh, was very voluminous, and should be suitable for paint since it settles slowly. The microscopic plates and spangles give a paint of good covering power. The samples made contained impurities which would not be present if nickel equipment was used. The dust is very fine and more reactive than the coarser dust and, by the same token, is much more difficult to melt down into molten zinc. A modest-sized plant could produce the higher priced dust without causing overproduction of this commodity.

Naturally a comparison is difficult to make between work done with unlimited financial resources and equipment, with a large staff of personnel, and the work done solely by Morgan and Gray with very limited financial resources.

C. T. Baroch: Congress established the Bureau of Mines, among other things, to conduct technologic investigations concerning mining, treatment, and utilization of mineral substances.[27] In selecting problems for study the Bureau always tries not to duplicate work being done by private or other public agencies.

Wartime demands revived attention to the oxidized zinc deposits of the country. These appeared to be ideal subjects for Bureau metallurgical research because no one seemed to be doing much to utilize them. Few of the deposits are large, as ore reserves go, and none has been extensively developed because the zinc could not be disposed of at a profit. In many deposits, particularly in the Southwest, the oxidized zinc goes deep and in some mines has been by-passed to mine deeper sulfide ores which could be concentrated and shipped profitably. Nevertheless, these oxidized-zinc deposits are numerous, and many of us believe they aggregate a worthwhile reserve.

The building of Basic Magnesium at Henderson, Nevada, in 1942, brought caustic soda, as a by-product of the chlorine plant, within easy reach of some zinc districts. It was only natural that this should revive thinking about caustic leaching. Some laboratory work was started at the Reno station of the Bureau in 1942 under the direction of the late Edmund S. Leaver and, later, of A. C. Rice. These workers were aiming at a chemical precipitation process in which the zincate solution was carbonated to precipitate the zinc. The project was never completed because of lack of funds and the pressure of other more urgent projects.

When the pressure of war work subsided, the problem was resumed at Boulder City in 1946 and resulted in the process described in our paper. We had no way of knowing about Mr. Morgan's work in 1940. By the time he resumed his work in 1948, the basic ideas of our process were sufficiently established to have attracted the attention of Basic Reduction Company which cooperated with the Bureau in financing pilot-plant operation on certain phases of the process.

Messrs. Morgan and Gray beat us to publication, however, with their article in *Engineering and Mining Journal*, which we regard very highly and are glad that someone shares our opinion regarding the feasibility of treating oxidized zinc ores. As the work of only two people, their work is especially creditable. However, contrary to Mr. Morgan's inference, no Bureau work is "done with unlimited financial resources..." Congress appropriates money only after a project has been severely reviewed and approved within the Bureau and then by the Bureau of the Budget. Unless a project has some strategic importance or receives a nod of approval from some defense agency, it had little chance of survival in recent years. Even so, the money requirements may be trimmed almost beyond recognition from the original engineering estimate. The zinc project has received about the smallest appropriation of any of several being conducted at Boulder City. When the work first started, the money available supported one man full-time and another part-time. Later appropriations increased slightly, but the "large staff of personnel" at its best consisted of four people and a part-time supervisor.

Finally, I would like to correct a typographical error which occurred in our paper on page 70, end of the second paragraph, where "minus-35-mesh" should have read "minus-325-mesh."

[27] L. B. Moon, Bureau of Mines Rpt. of Investigations 4647, January 1950.

AMOUNT OF OXYGEN ON THE SURFACE OF PASSIVE STAINLESS STEEL

Herbert H. Uhlig and Samuel S. Lord, Jr. (pp. 216–221)

Earl A. Gulbransen[28]: 1. I would like to bring to the attention of this group the very interesting electron diffraction studies of Professor G. I. Finch's group of the Imperial College of Science in London. Professor Finch's group has found that the reflection electron diffraction method can be used to study amorphous oxide films on electropolished metals and other apparently clean surfaces if one uses a grazing angle of a few minutes instead of the more conventional grazing angles of 20–60 min. Using single crystals of the metals, Professor Finch has shown that the typical cross array of spots characteristic of the metal is obtained at the usual grazing angles, while amorphous rings are obtained when the angle is reduced to a few minutes.

This technique when applied to systems such as those studied by Professor Uhlig will add new information on

[28] Chemical Department, Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.

whether we should consider the oxygen pickup as an oxide film or an adsorbed layer. To electrons of energies greater than 40,000 volts it is difficult to visualize an adsorbed layer giving an electron diffraction pattern of the type described by Professor Finch.

2. I would also like to comment on Professor Uhlig's assumptions in his calculations on the thickness and density of the adsorbed layer. Professor Uhlig has used the covalent radii of 0.7 Å for the chemisorbed oxygen atom layer and a radius of 1.3 Å for the molecular adsorbed layer on top of the chemisorbed layer.

I think these values for the radii should not be used for the following reasons. First, the close-packed layer of oxygen ions in the iron oxides gives an oxygen ion radii of something greater than 1.35 Å. This, in turn, would give the area for an oxygen ion adsorbed on a surface of nearly four times that assumed by Professor Uhlig. Second, if one assumes that each iron atom on a cubic plane of iron adsorbs one oxygen atom, the area of such an oxygen atom is equivalent to that calculated using a radius of 1.43 Å. If Professor Uhlig's assumptions were true, each iron atom on the cube plane would have nearly four oxygen atoms associated with it. This seems rather unlikely. Third, if the second layer of adsorbed molecules is physically adsorbed, the value of 1.3 Å radius for the oxygen molecule is much too small when compared to known areas of oxygen in the liquid or solid state.

On the basis of these comments, I think Professor Uhlig's data give support to the oxide film theory rather than to the adsorbed layer modification.

H. H. Uhlig: Electron diffraction techniques of the kind under study by Professor Finch are important to further progress in metal surface studies as Dr. Gulbransen outlines. Among the difficulties in the path of those who have attempted such studies in the past are the extreme thinness of adsorbed films, the thickness in general being below the limit necessary for a diffraction pattern. Also, the tendency of high energy electron beams impinging on a metal is either to remove the adsorbed gas layer, or to initiate chemical reaction of the film with the metal to form a stoichiometric compound that was absent before the metal was placed in the electron diffraction equipment. In either case, subsequent patterns are not characteristic of the original surface. The techniques using low energy electron beams overcome this difficulty, but the experimental problems of electron diffraction are enormously more difficult and have, to a large extent, discouraged attempts to study adsorbed films in this way.

The problem of assigning the correct atom radius to an adsorbed film has not been resolved, again because techniques for measuring thicknesses of adsorbed films are not yet developed. The assumed atomic radius, therefore, whether covalent or ionic, is based on conjecture and not on experiment. However, there are certain principles upon which one can depend in arriving at a reasonable answer. The first principle is that the total energy of adsorption per mole of oxygen adsorbed may actually exceed the heat of reaction for the corresponding metal oxide. Langmuir and Villars[29] showed that the heat of adsorption of oxyge on tungsten is equal to 320 kg cal/mole compared with heat of reaction equal to 134 kg cal/mole of oxygen form WO_3. This indicates that the bonding of oxygen metals in adsorbed films differs from bonding in oxide and, in general, may be stronger in the case of adsorbe films. Pauling[30] has shown that the stronger the interatom bond, the closer do atoms approach each other. Further more, and even more important, the distance of approac decreases the smaller the number of neighbors for each the atoms. For example, the distance between carbo atoms in the C≡C bond where each carbon atom has tw neighbors is 1.2 Å, whereas for the C—C bond, where eac carbon atom has four neighbors, the interatomic distanc is 1.5 Å.[31] Hence, it follows that the distance of oxyge to an 18-8 surface, where oxygen as part of an adsorbe film has fewer neighbors, must be less than the separatio of Fe and O in Fe_2O_3. The radius of oxygen chemisorbe on 18-8, therefore, more nearly approaches the covalen radius. One property of such chemisorbed films is th there need not be a stoichiometric ratio of oxygen to iro atoms, as ind ed has also been found true of oxide com positions such as FeO, where the Fe to O ratio may var within relatively wide limits.

Another approach to the radius of chemisorbed oxyge can be made through the x-ray lattice determinations Jette and Foote[32] for FeO. They reported a lattice parame ter of 4.330 Å (or less depending on composition), makin the FeO interatomic distance equal to 2.165 Å. Assumin iron in the body-centered cubic lattice to maintain i characteristic radius of 1.27 Å, which is a reasonable ap proximation, the radius of adsorbed oxygen is 2.165 − 1.27 = 0.895 Å which is considerably less than the ion radius. Factors depending on number of neighbors an strength of bonds as discussed above would reduce th value still further.

The second layer of oxygen over the first chemisorbe atomic layer is not dissociated because the energy adsorption falls off as the number of adsorbed layers in creases. It is reasonable to assume, therefore, that molec lar O_2 adsorbs as a second layer and that the radius this layer is somewhat less than the radius assigned molecular oxygen because of interaction with the fir layer of chemisorbed oxygen. The Van der Waals radi for the free oxygen molecule is given as 1.45 Å, so that a assumed radius of 1.2 Å does not seem far out of line. O one can also logically use a larger value for the molecul radius and assume that a close-packed molecular layer covered by a partial third layer of oxygen molecules sti less tightly held than the layer below. The total evidenc in either case supports, so we believe, the adsorbed g model for passivity in stainless steels.

[29] I. Langmuir and D. Villars, *J. Am. Chem. Soc.*, **53**, 486 (1931).

[30] L. Pauling, *J. Am. Chem. Soc.*, **69**, 542 (1947); "Th Nature of the Chemical Bond," Cornell University Pres Ithaca, N. Y. (1948).

[31] H. H. Uhlig, "Metal Surface Phenomena," chapte of "Metal Interfaces," pp. 312–335, American Society fo Metals, Cleveland, Ohio (1952).

[32] E. R. Jette and F. Foote, *J. Chem. Phys.*, **1**, 2 (1933).

CORROSION OF HEATING ELECTRODES IN MOLTEN CHLORIDE BATHS

H. R. Copson (pp. 257–264)

ANTON DES. BRASUNAS[33]: Corrosion in molten salts is indeed a complex problem, and Dr. Copson is to be commended in attacking it.

In analyzing the data and extrapolating to zero current density, the curves of Fig. 2 and 8 indicate that the Inconel rods might be attacked more severely with fresh salt than with 1 per cent Na_2CO_3 added (a reverse of findings with applied current), which might be explained by the "oxidizing power in fresh salt." Has the dissolved oxygen content, Na_2O, or carbonate been determined for the fresh salt to verify that this is so? It has been stated that molten salt "reacts with moisture and air to form oxides and carbonates" suggesting that the oxidizing power of the salt might increase with time. Presumably, the corrosion reaction without applied current would be either:

$$\text{metal} + \text{oxygen} \rightarrow \text{metal oxide} \qquad \text{(I)}$$

or

$$\text{metal} + \text{NaCl} + \text{air} \rightarrow \text{metal chloride} + Na_2O \qquad \text{(II)}$$

The oxygen in equation (I), being dissolved or combined in the molten salt, is provided by the atmosphere. In the second equation, which is less likely, the sodium oxide might react further to form NaOH, Na_2CO_3, or some other salt.

With regard to the dull gray area, a section of which is shown in Fig. 5 which "readily took the copper plate tending to prove a metallic coating," it seems that this conclusion is open to question and that a more positive method such as x-ray diffraction might be more satisfactory. The nature of this deposit may be of great importance in determining the mechanism of deposition. Copper plating can easily be applied to graphite-impregnated nonmetallic surfaces or other conducting nonmetallic surfaces. Furthermore, both FeO and Fe_3O_4 are fairly good electrical conductors and would take a copper plate.

The writer is aware of the general coverage that the term corrosion implies, and since the so-called "pencilling" reaction is attributed not to the chemical or electrochemical reaction of the Inconel rods with their natural environment, but with the anodic part of an impressed a-c cycle, he wonders whether the author considered the suitability of the term corrosion for this phenomenon.

The detection of no corrosive attack, of the solution-deposition type, in fresh pure salt is surprising, especially when one considers the excessive temperatures which were encountered. Has the author attempted, or considered maintaining, this desirable condition artificially and indefinitely by maintaining the system in an inert atmosphere? If this can be done, the individual variations in chemical environment such as oxygen, moisture, CO_2, etc., might more easily be evaluated and thus, perhaps, lead to a better understanding of molten salt corrosion and the factors which favor rapid attack.

H. R. COPSON: It might be well to point out that the rate of attack during pencilling was exceedingly high. Thus a rate of 5 gram/in.^{2}/day, which was fairly common, is equivalent to 77,500 mdd or 13 ipy. In view of this, it does not seem safe to extrapolate Fig. 2 and 8 to zero current density. The normal rate of corrosion as given by the intercept would be subject to large error. Unfortunately, no experiments were made without applied current. The normal rates of corrosion would, however, be comparatively low. In Fig. 2 it is quite possible that the data should be represented by a curve instead of a straight line.

With reference to the composition of fresh salt, it was stated in the paper that analyses showed no appreciable change in composition during the 18-hour runs. In other words, the Na_2O content as determined by titration, the CO_2 content as determined by evolution, and the chromium content were negligible. No attempt was made to determine dissolved oxygen.

Dr. Brasunas writes two reactions. The author had in mind another one involving carbon dioxide dissolved or combined in the salt:

$$\text{metal} + CO_2 \rightarrow \text{metal oxide} + CO$$

The comments about the dull gray area shown in Fig. 5 seem well taken. It should be noted, however, that these areas were strongly magnetic, and appeared, upon magnification, as though built up with a metallic nickel electrodeposit. The point that was being made was that something was plating back on the electrodes, and this point is considered proved.

With reference to the use of the word corrosion, we regret that Dr. Brasunas did not suggest a better term. In the paper, the word pencilling was coined and used, but nothing better than corrosion suggested itself for the title.

In the paper it was stated that better control of the salt bath composition was desirable. In any future work attention should be paid to this factor. Controlling the composition of the gas phase is a logical way to proceed.

No one will argue with the statement that corrosion in molten salts is a complex problem. Attention might be called to a recent paper on the subject.[34]

PREPARATION AND PROPERTIES OF IODIDE VANADIUM

Julian W. Nash, H. R. Ogden, Richard E. Durtschi, and I. E. Campell (pp. 272–275)

D. WROUGHTON[35]: How was the spiny nature of the deposits which were obtained in early work overcome?

JULIAN W. NASH: The conventional de Boer process was used in early work. A straight flow process, in which the decomposition products were continuously removed from the bulb, gave smooth deposits.

WALTER LEE ROBB[36]: What per cent of the vanadium is converted to the iodide during the iodinization step? Are you able to reiodize the remaining vanadium?

JULIAN W. NASH: The per cent of vanadium converted to iodide is low. It varies between 10 and 15 per cent. No difficulty was encountered in iodinating the remaining vanadium.

[33] Department of Chemical Engineering, University of Tennessee, Knoxville, Tenn.

[34] J. H. JACKSON, "Cast Alloys for Salt-Bath Heat Treating," Alloy Casting Bull. No. 16, November 1952.

[35] Westinghouse Electric Corporation, Pittsburgh, Pa.

[36] Knolls Atomic Power Laboratory, General Electric Company, Schenectady, N. Y.

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TB 111

Editorial

World-Wide Electrochemistry

THE vast contribution of industrial electrochemistry to modern life which has been portrayed in part in the anniversary feature articles in this JOURNAL during the past year suggests the importance of a survey of the status of industrial developments in various regions of the world. Accordingly, it is planned to publish during 1953 a series of papers sponsored by our regional editors and describing the status and progress of industrial electrochemistry. In keeping with the international character of this Society, the first article of this series will present recent developments in India where such strides are being made toward industrialization. Justice Douglas in his recent adventurous and discerning books, "Strange Lands and Friendly People" and "Beyond the High Himalayas," has pointed out the importance of bringing to the peoples of Asia technical knowledge at the level of those who are to make use of it, that is, to the farmers, tradesmen, village dwellers, and professional people. This Society, through its meetings and publication of scientific and engineering knowledge, makes an important contribution toward this end. Our growing India Section is doing much to stimulate developments in that country. This enterprising group has its own publication known as the "Bulletin of The India Section of The Electrochemical Society." It is both appropriate and opportune to reprint here the excellent editorial from the July 1952 issue of that publication by its Chairman, M. S. Thacker.

—RMB

Electrochemistry and The Electrochemical Society

"This is a period of intensive application of science and technology to industry. Electrochemistry is uniquely qualified to lead in the envisaged industrial expansion of the country today. Its processes are direct, closely controllable and adapted to the mass production of things which are basic to industry at large. The products can be pure in quality, low in price, and in large quantities. Electrochemistry has evidence of great importance in national economy. Development of new products, industries, and process improvement would reduce cost of manufacture of materials and ensure their wider distribution. To make this contribution to the future economy electrochemistry requires abundant and cheap power to operate processes, research to develop new products, and trained engineers to direct technology. Technological changes must occur now at a more rapid rate than ever before. Technical development must

be stimulated and accelerated to cause the industrial economy to move to new levels. Research and Engineering must exhibit their ingenuity in finding solutions to complex problems. The electrochemist has to shoulder increasing responsibilities in the development of new industries for employment and enhancement of living standards.

"Any development emphasizes the interdependence of numerous sciences and great advantages would accrue from close co-operation by those skilled in many branches. Electrolytic and electrothermal processes aid in the conservation of natural resources by their economy in the use of raw materials and their ability to utilize low-grade minerals in reduction processes.

"The availability of large blocks of power from hydro and thermal projects would promote interest in industrialists to develop raw materials and manufacturing possibilities within their reach. This involves broad consideration of raw materials, home market and cost of production. The Electrochemical Society would assist in all promotional activities. The Society would not only render promotional publicity work with the nation's natural resources but also disseminate technical information and publicize economic papers describing specific projects. It would work as a co-ordinator of many developments in science and engineering. Whatever information can thus be published would be of use to research workers and industrialists. The Society would serve as a clearing ground for scientific information on electrochemical progress which is having a profound effect on our material civilization.

"It is the privilege and duty of scientific and technical men to conceive better conditions and better products leading to greater human happiness. The meetings of the Society will provide forums for the discussion of research and the development of inventions. The JOURNAL, which is the mouthpiece of the Society's activities, is hospitable to research articles relating to science which originate from laboratories and industries. It is hoped that the Society will be the instrument for the accomplishment of notable scientific and industrial contributions to the expanding chemical industry in India."

THE DEVELOPMENT OF THE ELECTROCHEMICAL INDUSTRY IN INDIA

T. L. Rama Char[1]

Electric Power Production

It has been considered that the plans for the industrialization of undeveloped countries invariably begin with the production of electric power and its distribution at important ad centers at reasonably low rates. In India, power generation from coal resources is restricted to a small section of the ountry in West Bengal and Bihar and, therefore, the remaining part would have to depend to a large extent on ydroelectric power for which, fortunately, there are abundant ater sources combined with suitable topographical features nd concentration of rainfall in appropriate places. Although e present total power-generating capacity is less than 2 illion kw of which about 30 per cent is hydroelectric power, conditions are favorable, it is expected that about 7 million w may be available during the next 10 to 15 years.

On account of the restricted supply of coal and other fuel the country, recourse will have to be had for the utilization f electric power for certain electrochemical and electrometallurgical processes, to develop the important key industries which would be essential for the country for its normal evelopment and for purposes of defense. In certain advanced ountries like Sweden, Canada, the United States, and .S.S.R., a fairly large percentage of the power generated is eing used for electrochemical and metallurgical industries. n some cases, it is as high as 25 per cent. An important factor hich has contributed this large percentage of utilization of ectric power for such industries is the availability of electrical energy at a comparatively low rate. The Scandinavian ountries are reported to provide the lowest rate of energy of he order of 0.1 cent per kwhr (0.05 anna). In Canada, it anges from 0.1 cent to 0.25 cent (0.05 to 0.08 anna). Even t a higher rate of energy, say about 0.5 cent per kwhr 0.25 anna), it would be possible to make it economically easible to develop certain electrochemical and metallurgical ndustries.

About 40,000 kw of power are now utilized for these ndustries in India which account for nearly 10 per cent of he total energy sold. It is estimated that out of this 40,000 w, nearly 25 per cent is absorbed by the aluminum industries, bout 12½ per cent by the steel industries, 30 per cent by lkali-chlorine and fertilizer industries, and the balance by errоalloys and nonferrous metals and other heat-treatment rocesses.

The location of major electrochemical and metallurgical ndustries close to the source of power is an important factor hich makes these projects economically feasible and capable of competing with imported products. The local market is another factor which is essential and is likely to be available in the country, just as in the case of the United States, Canada, and the U.S.S.R. The immediate requirements of the country are the production of aluminum, special types of steel, ferroalloys, alkali and chlorine products, and some essential materials which can only be manufactured by the electrochemical-thermal processes such as ferrosilicon, calcium carbide, metaphosphates, abrasives, etc. Some of the members of The Electrochemical Society have carefully studied the various aspects of these problems as well as the optimum ratio of the cost of energy to the total cost of the finished products and considered it feasible to develop these industries to a larger scale in the future. Even though the costs have increased because of the dependence of the country on imported machinery and equipment for power generation as well as for its utilization, the day is not far off when a large percentage of this equipment would be made in the country and thus contribute to a reduction in the cost of energy.

Caustic Soda and Chlorine Production

The trend of development during the last two decades and the probable extension hereafter are noted below.

A beginning was made nearly 25 years ago to produce caustic soda and chlorine by the electrolytic processes to meet the requirements of the paper and textile industries. Production has steadily increased since then and independent chemical works have been established to manufacture these products. Among them the Mettur Chemical & Industrial Corporation Ltd., Mettur Dam, the Alkali and Chemical Corporation of India Ltd., Rishra, and the Tata Chemicals Ltd., Mithapur, may be mentioned. The D.C.M. Chemicals, Delhi, and the Sarabhai Chemicals, Baroda, are examples of a group of textile manufacturers who have expanded their alkali-chlorine plant to supply the general requirements of the country. The capacity and production of the various electrochemical-metallurgical plants are shown in Table I. Besides the demand for caustic soda of the commercial grades produced in the typical diaphragm cells, there is now a demand for caustic soda of the highest purity required for the rayon industry which is being established rapidly in Bombay, Hyderabad, and Travancore-Cochin. The Fertilizers and Chemicals, Travancore, Ltd., have started to manufacture such high quality caustic soda in their works at Alwaye by means of mercury cells.

In all these plants modern methods are being adopted for processing the primary products, recovery of the by-products, and proper distribution to the consumers. Since it is well known that the effective utilization of chlorine improves the

[1] Regional Editor for India. Indian Institute of Science, Bangalore, India.

economy of the alkali-chlorine industry, efforts are being made to fully utilize this valuable by-product. In some plants hydrochloric acid is being produced and in others, efforts are being made to manufacture chlorinated organic compounds such as D.D.T., polyvinyl compounds, etc. Caustic soda is being sold in the form of concentrated liquor, solid blocks, and flakes. Because of keen competition from imported products, special tariffs are employed temporarily which may be withdrawn when no longer needed.

Other electrolytic products such as hydrogen, oxygen, potassium chlorate, and hydrogen peroxide are being manufactured on a small scale. In one plant, however, hydrogen is being produced mainly for the manufacture of ammonia by the synthetic process and at a reasonably low cost. It is expected that the utilization of hydrogen in this manner will increase hereafter on account of the scarcity of coal and other gas-producing materials in the country.

There is a good scope for pioneer investigations to ascertain the suitability of certain raw materials to be used in these electrochemical processes.

TABLE I. *Statement showing the capacity and production of certain electrochemical-metallurgical products in India*

Name of product	Present demand tons/yr	Existing production capacity tons/yr	Demand in 5 years tons/yr	Additional production target tons/yr	Power and energy required	Name of firm and capacity (tons/yr)			
							Caustic soda	Bleaching powder	Liquid chlorine
Caustic soda	50,000	17,630	13,300	45,000	22,500 kw	Mettur Chemical and Industrial Corp. Ltd.	4000	2000	800
Chlorine		6540		40,000	138 × 10^6 kwhr	Tata Chemicals Ltd.	8000	4000	—
						The Alkali and Chemical Corp. of India Ltd.	1600	—	1500
						Rohtas Industries	530	2700	—
						DCM Chemicals.	4000	—	800
Ammonium phosphates				50,000	7500 kw				
Calcium metaphosphates	600	113,200	100,000	50,000	56 × 10^6 kwhr				
Phosphorus	800	Not ascertained	25,000	24,000	48,000 kw 340 × 10^6 kwhr				
Anhydrous ammonia	25,000	1500 + Sindri 75,000	40,000	32,000	70,000 kw 480 × 10^6 kwhr	Mysore Chemicals and Fertilisers	1500 tons		
						Fertilisers and Chemicals, Travancore	12,500 tons		
						Sindri Fertiliser Project	75,000 tons		
Hydrogen peroxide	50 (estimated)	Not ascertained	400	400	1200 kw 81 × 10^6 kwhr				
Carbon disulfide	—	—	8760	8760	1400 kw 9.8 × 10^6 kwhr				
Calcium carbide	3500	—	7000	7200	4200 kw 29 × 10^6 kwhr				
Carborundum	600	—	2000	2000	3000 kw 21 × 10^6 kwhr				
Ferrosilicon, 75% Si	4000	2000	6000	4000	5500 kw 40 × 10^6 kwhr	Mysore Iron and Steel Works	2000 tons		
						Future	4000 tons		
Ferrochrome, 60% Cr	1000 (estimated)	—	3000	2000	4000 kw 30 × 10^6 kwhr				
Aluminum	10,000	7400	20,000	20,000	64,000 kw 480 × 10^6 kwhr	Indian Aluminium Co.	5000 tons (2400 actual)		
						Aluminium Corp. of India Ltd.	5000 tons (1200 actual)		
Special steels	6000 (estimated)	5000	10,000 (estimated)	10,000	10,000 kw 70 × 10^6 kwhr				
Pig iron (special)	1,750,000 (Tariff Board Report)	—	3,000,000 (estimated)	84,000	27,000 kw 236 × 10^6 kwhr	Mysore Iron and Steel Works	60,000 tons (30,000 in 1953 actual)		

FIG. 1. Hooker "S" type caustic chlorine cells of The Mettur Chemical & Industrial Corporation Ltd., Mettur Dam, India.

Among the electrothermal industries, the production of ferroalloys and aluminum takes an important place and both have been established on a sound footing.

Ferroalloys and Aluminum

Ferrosilicon is being produced at the Mysore Iron & Steel Works, Bhadravati, to meet immediate requirements of the large steel works such as the Tata Iron & Steel Company, Steel Corporation of Bengal, etc. This industry is being expanded considerably in order to meet all the requirements of the country by the installation of larger furnaces. Other ferroalloys such as ferrochrome, ferromanganese, etc., are very important items on the future program of the country, especially as large quantities of the raw chromite ore and manganese ore are being exported annually from the various ports of India. The extension of hydroelectric power at Jog Falls in Mysore and Machkund in Madras, as well as the Koyna project in Bombay, will contribute to the development of these industries.

The production of aluminum is of vital importance to India, especially since the country has no appreciable resources of copper ores. If, therefore, the future electrical power industry is to be on a sound footing, the production of aluminum on a large scale must be undertaken. It is very fortunate that two companies have already started functioning: The Indian Aluminium Company, Ltd., at Alwaye, and the Aluminium Corporation of India Ltd., at Asansol. Each of these plants was originally designed for 5000 tons annual capacity. Their actual production is less than half that, but it is expected in the near future that their capacity will be brought up to the originally proposed figures. Since even this is inadequate, further extension to about 25,000 tons per year is necessary either by increasing the capacity of the existing plants or by installing new plants close to the source of bauxite ore and within a reasonable distance of the source of power. Such sites are available in the Bombay, Bihar, and Madhya Pradesh areas. Besides the use of aluminum for the electrical industries, there is an enormous demand for aluminum plates in the manufacture of household utensils, as well as for the manufacture of automobiles and aircraft in the shape of aluminum alloys. Since both these latter industries are being established, it will not be long before the production of aluminum alloys is undertaken in the country.

Although there is scarcity of copper in India, it is a matter for consideration whether a large copper refinery plant is worth establishing in order to reclaim large quantities of scrap copper available annually in the country. Investigations are being made to ascertain the most economical location for such a plant. Probably the proximity of large cities and large railway termini would be most favorable, say, near Bombay, Calcutta, or Madras. The Indian Telephone Industries Ltd., Bangalore, the Premier Automobiles, Bombay, and Hind Cycles, Bombay, have installed modern equipment for electroplating.

A matter of great importance and of immediate interest to electrochemical-metallurgical engineers is the establishment of two electric pig-iron furnaces at the Mysore Iron & Steel Works, each capable of producing 100 tons of high grade pig iron per day. The total power required for the two furnaces would be of the order of 30,000 kw. It is also likely that this will be coupled with the installation of two electric-steel furnaces of 20 tons capacity each to work in conjunction with a Bessemer plant to produce mild steel billets required for light structural and other common purposes.

Centers of Industry

From the general planning of development, the following seem to be likely centers of electrochemical and metallurgical industries:

(*a*) Mysore Iron & Steel Works, Bhadravati, and Mysore Chemical and Fertilisers, Belagula, (*b*) Fertilisers & Chemicals, Travancore Ltd., Alwaye, Indian Aluminium Company Ltd., Alwaye, and the Travancore Electro-Chemical Industries Ltd., Kottayam, and (*c*) areas near the few power plants in Madhya Pradesh and Bombay States, and Damodar Valley and Hirakud.

The production of graphite electrodes required for electrolytic cells and electric furnaces, abrasives, calcium carbide, and allied products is being undertaken in Travancore where conditions are favorable. It may be possible to make the country self-sufficient in these products in a few years.

It is encouraging to note that several firms engaged in engineering and metallurgical industries have found it economical to install electric furnaces of the induction as well as resistance types. Chief among them are the Bombay Mint, the Kamani Metal Works, Bombay, and groups of iron and steel works in Calcutta, Bombay, and some parts of Uttar Pradesh.

FIG. 2. Cell house in the caustic soda plant of The D.C.M. Chemical Works, Delhi.

In one factory manufacturing porcelain products, the Government Porcelain Factory, Bangalore, a modern electric tunnel kiln has been installed for the manufacture of high-tension electric insulators. For production of primary and secondary batteries several factories have been established in Bombay, Calcutta, and Bangalore. The General Motors Corporation Ltd., Bombay, and Standard Batteries, Bombay, have put up large self-contained factories for the manufacture of lead-acid storage batteries required for various purposes. The latter firm has the most up-to-date equipment for the manufacture of all the parts including hard rubber containers, battery plates, separators, and the active materials for the battery.

It is a matter of great importance for those interested in electrochemical and metallurgical industries that the Council of Scientific & Industrial Research, India, has started the establishment of a Central Electro-Chemical Research Institute at Karaikudi. The Indian Institute of Science, Bangalo has well established laboratories and technical personnel f research and teaching in electrochemistry and electromet lurgy. Plans are afoot for the introduction of specializ courses in electrochemistry in the Indian universities. The efforts will go a long way toward providing the technic personnel required for manning the electrochemical industri in the country. It is earnestly hoped that development electrochemical industries as well as research and teaching electrochemistry and electrometallurgy will go on at a ve rapid pace in the near future.

Acknowledgment

The India Section of The Electrochemical Society wish to express its sincere thanks to the Patrons of the Sectio firms and individuals who readily furnished information co cerning their activities in the electrochemical field.

Current Affairs

William Blum Awarded Honorary Membership

William Blum, former President of the Society, dean of American electroplaters, and for many years a member of the staff of the National Bureau of Standards, was presented with Honorary Membership in The Electrochemical Society, at the Montreal Meeting on October 27.

George B. Hogaboom, long-time Society member, commented on Dr. Blum's achievements as follows.

To give the story of the accomplishments of Dr. Blum at this time would only be to repeat what Dr. H. S. Lukens stated upon the presentation of the Acheson Medal to Dr. Blum in 1944. Mr. Thomas P. Slattery told of his personal life [TRANSACTIONS, Vol. 86, p. 13 (1944)].

When we worked with him during World War I we lived at his home and it did not take us long to learn to love both him and his fine wife who made the home so happy.

He has added greatly to the lore and to the progress of the electroplating industry. He has brought out many things. His greatest accomplishment, however, has been to inspire in others the will and determination to work and to do things that are far better for the industry than has been done.

I would like to recall what he has been doing for the Society. He attended his first meeting at Atlantic City in 1912, where we met him for the first time, and he became a member of the Society in 1914. In 1922 the Electrodeposition Division was formed; he was elected its secretary. In 1926 he became president of the Society, and in 1929–30 was chairman of the Publications Committee. In 1944 he received the Acheson Medal.

He has contributed twelve papers to the TRANSACTIONS and has been coauthor of twelve others. He has taken part in 163 recorded discussions, always willing to tell what he knew and help others have a better idea of what was going on. How many times he, in personal discussion, has augmented the knowledge of others cannot be estimated.

DR. BLUM, with Society President J. C. WARNER (*right*) and GEORGE B. HOGABOOM (*left*) receives certificate of Honorary Membership in the Society.

At the reception given him when he retired from the Bureau of Standards every division of the Bureau was represented. He was presented with a copy of the talks he had given—100 in all!—bound in three volumes. When I said he lived a full life there can be no better evidence than that.

He has worked with the American Electroplaters' Society, and instituted and supervised technical researches. You recall the protective value of electroplated coating research and exposure tests. Tests were made to evaluate the life of such coatings and from that build up specifications for electroplating. The physical properties of nickel deposits were investigated.

Those of you who have read his work with Dr. Abner Brenner know that to be one of the most thorough pieces of research work that has come before the electroplating industry; other problems were the effect of polishing on protective values, dropping tests, spotting out, and so many others that it is not possible to list them.

I stated that one of the most valuable things a man can do is to inspire in others the will to go ahead and be something in industry. Those who worked with him and went into other fields he liked to call his "alumni." Permit me to list some of them: Thomas F. Slattery, Assistant Director of the Bureau of Engraving and Printing; F. J. Liscomb; H. D. Holler, corrosion research, National Research Laboratory, Washington, D. C.; R. M. Wick, electrodeposition research, Bethlehem Steel Co.; R. O. Hull (the Hull cell), President, Electroplating Supplies Co., Cleveland, Ohio; R. A. Dimon, electrodeposition research, Carnegie-Illinois Steel Co.; H. L. Farber, electroplating, Westinghouse Electric Co., Mansfield, Ohio; G. A. Lux, Oakite Products Co.; W. P. Barrows, electroplating research, and specifications, U. S. Navy Yard, Washington, D. C.; C. W. Jennings, professor of chemistry at the

University of North Carolina, Raleigh, N. C.; William Sosnow, Philadelphia Naval Shipyard; N. Bekkedahl, rubber chemist for the Bureau of Standards, Washington, D. C.; Mrs. Polly Burkhead, graduate researcher at Lehigh University; Mrs. Thelma Steinberg, researcher at Yale University; Miss M. Sullivan, metallurgist, Naval Research Laboratory, Washington, D. C.; C. T. Thomas, chief of the Electrodeposition Division, Bureau of Engraving and Printing; W. A. Olson, assistant chief of the Bureau of Engraving and Printing; H. E. Haring (Haring cell), Bell Telephone Laboratories, Murray Hill, N. J.; W. E. Bailey, chemical division, National Production Authority, Washington, D. C.; A. D. Bell, consultant, St. Paul, Minn.; Victor Zentner, Surface Alloys Corp., Los Angeles; Robert Seegmiller, Atomic Energy Commission, Los Alamos, N. Mex.; Mrs. Zalia Jencks Gailey, lecturer at the University of Washington, Seattle, Wash.; and George B. Hogaboom, Consultant, New Britain, Conn. He built up a staff to succeed him under the able direction of Dr. Abner Brenner. They are the ones that he inspired to carry on further work and become well known in his beloved industry.

He has done work that has been so outstanding that he has received honors one after the other: a medal from the Institute of Chemists in 1926; the Acheson Medal in 1944; a medal from the Department of Commerce in 1951; Award of Merit from ASTM in 1951; a special award from the Frankford Arsenal in 1951; Honorary Membership and life honorary membership of the Research Committee, A.E.S.

All I need add is, well done, thou good and faithful servant, well done.

* * *

Dr. Blum responded in these words.

President Warner, George Hogaboom, and members of The Electrochemical Society. I am deeply grateful for this Honorary Membership in an organization that has meant so much to me. This honor was made possible by the loyal and cordial cooperation of my many associates at the National Bureau of Standards, and in the committees of this and kindred societies. What has been accomplished is the result of teamwork.

You will note that the program calls for a "response" by the recipient, and not a speech or an address. As all such remarks are supposed to be impromptu, I will not read my carefully prepared speech!

When I was notified of this honor, a question occurred to me that may sound like looking into the mouth of the proverbial "gift horse." "What is the excuse for the existence of The Electrochemical Society (or for that matter, of any highly specialized scientific society)?"

This is a day of increasing specialization, as illustrated by the use of "offensive" and "defensive" football squads. (It is even rumored that one team has an offensive and a defensive chaplain!)

It is no longer possible for a person to be a scientist or even a chemist; he must restrict his activities to a narrow field if he is to accomplish anything. The rise of special organizations such as The Electrochemical Society, and even of those with much narrower fields, such as electroplating or electrotyping, is a recognition of the value of bringing together those persons with common interests, so that they may share their knowledge, and even more important, may come to know personally (and argue with) their fellow workers. It is not necessary to justify these aims and activities.

It may be wise, however, to emphasize the fact that application of scientific knowledge can proceed only if more fundamental knowledge is coming from its sources. Even though at a given period the practice in a certain field may surpass the existing theories, development and understanding of the latter are necessary for continued progress. There are two ways in which this happy relation between theory and practice can be brought about.

First, it can be attained through the devotion of part of the time and energy of the special societies to the study of fundamentals. This practice is well illustrated by the activities of the Theoretical Division of the Society.

The second way is through individual and group association with those organizations that have broader fields, such as the American Association for the Advancement of Science and the American Chemical Society. Membership in multiple societies is a burden on one's pocketbook and on the time required to attend meetings and read the journals, but apparently this is the price of progress in science. If I may make a personal reference (no doubt shared by many present) I have found it necessary, in order to keep up with electroplating, to join the AAAS, the ACS, The Electrochemical Society, the Faraday Society, the American Electroplaters' Society, the Electrodepositers' Technical Society (now the Institute of Metal Finishing), and the ASTM. While, of course, it has not been possible for me to attend all their local and national meetings, I have at times justified my attendance at a local section to hear a paper on a subject of which I knew nothing, by the thought that in one hour I could increase by 1000 per cent my knowledge of that subject!

This problem of specialized vs. fundamental science is very important in our educational system. In recent years concern has properly been expressed over the dearth of and need for courses in electrochemistry to meet the needs of this rapidly growing field. It is encouraging to note that recently the General Motors Corporation has endowed a fellowship at the University of Michigan for basic research in electrochemistry. Wisely this is a graduate fellowship, the requirements for which will no doubt include undergraduate studies in mathematics, physics, and chemistry. Only thus can we look for real progress.

If now I attempt to answer my original question, it seems that the place or function of The Electrochemical Society is twofold, viz., to increase the specialized knowledge of its members, and to stimulate them to learn as much science outside of their immediate field as possible. I believe that we are doing a good job in that task.

Top Scientists Explore Electroluminescence

The two top scientists in the field of electroluminescence, the illumination exhibited by a phosphor-coated flat glass panel when subjected to an electromagnetic field, are exploring this subject for the Westinghouse Lamp Division, Bloomington, N. J.

Professor Georges Destriau and Dr. Joseph Mattler, both from the Sorbonne, University of Paris, France, have been working in the Lamp Division research laboratories for about nine months on advanced electroluminescence experiments.

The scientists began studying the phenomenon in 1935, more than ten years before American lighting engineers suspected its possible commercial uses, and published joint papers on the basic ideas in 1936. In this country, they have been testing a new superior phosphor. Professor Destrian has now returned to France to continue experiments as a Westinghouse consultant.

New York Convention and Visitors Bureau

View of New York City's dramatic skyline, as seen from the harbor

New York Spring Meeting—April 1953

The 103rd General Meeting of the Society will be held in New York City at the Hotel Statler, April 12 through April 16, 1953. This is the sixteenth meeting to be held in New York City; the first meeting in New York was in 1903, just 50 years ago.

Technical Symposia

Plans are already far advanced for the Spring Meeting. There will be several interesting symposia, including an innovation in the nature of a Symposium on the Application of Electrochemistry to Biology and Medicine, supplemented by an exhibit of manufacturer's equipment used in this field. Sessions are being planned by the Electronics, Theoretical Electrochemistry, Electric Insulation, and the Electrothermic Divisions. The latter Division will have a series of previews by authors of the forthcoming monograph entitled, "High Temperature Materials, Methods, and Measurements." The Electronics Division is planning sessions on luminescence, screen applications, and semiconductors, and will have on sale an "Extended Abstract" booklet of the papers presented at their meetings. A Richards Memorial Lecture will be delivered on the subject of transistors and semiconductors. In addition there will be an enjoyable and well-planned Ladies' Program.

Hotel Accommodations

Since a large attendance is anticipated, members are urged to make their hotel reservations early. Hotel Reservation Cards will be mailed in February, but reservations can be made at any time. If the cards are not used, The Electrochemical Society should be mentioned in writing to the hotel.

Additional hotels, at which room reservations are available, include: Algonquin, 59 West 44th St., Barbizon-Plaza, 101 West 58th St. (Central Park South); Commodore, Lexington Ave. at 42nd St. (near Grand Central); Gramercy Park, Lexington Ave. at 21st St. (residential section); Park Sheraton, 202 West 56th St.; Penn Terminal, 215 West 34th St. (near Pennsylvania Station); Robert Fulton, 228 West 71st St. (overlooking the Hudson River); Tudor, 304 East 42nd St. (near United Nations);

COLIN G. FINK
Honorary Chairman

and Winthrop, Lexington Ave. at 47th St. (near Grand Central).

The program calls for the meetings of the Ways and Means Committee and of the Board on Sunday, April 12, 1953. The Society Luncheon and Business Meeting will be held Monday noon. There will be a popular speaker of general interest at this luncheon, and the ladies are specifically invited to attend. A dinner is scheduled for Monday in connection with the Symposium on the Application of Electrochemistry to Biology and Medicine, preceded by a reception and followed by a talk related to the symposium. All are invited to attend. The Reception and Banquet of the Society will be held on Tuesday, followed by dancing. The Richards Memorial Lecture will be presented late Wednesday afternoon. Other luncheons will be announced as soon as scheduling is definite. There will be simultaneous technical sessions on all the days of the convention. Details of these and other events will be announced later.

The Local Committee is hard at work arranging an interesting program for all members, guests, and ladies. This Committee is composed of Colin G. Fink, Honorary Chairman; H. R. Copson, General Chairman; K. G. Compton, Chairman of Advisory Committee; L. I. Gilbertson, Registration; H. Bandes, Entertainment; F. A. Lowenheim, Finance; G. A. Lux, Plant Trips; F. P. Peters, Publicity; A. C. Loonam, Arrangements; and Mrs. A. C. Loonam, Ladies' Program.

H. R. COPSON
General Chairman

Solvay Process Expands Soda Ash Facilities

Plans to proceed with the second step in the rebuilding of the soda ash manufacturing facilities at the Syracuse plant of Solvay Process Division, Allied Chemical & Dye Corporation, have been announced.

The newest project in Solvay's modernization and expansion program at Syracuse, involving practically a duplicate of the soda ash plant recently completed and dedicated, will require an expenditure for buildings and equipment in excess of $10,000,000. The preliminary work is to be started immediately and is expected to take nearly two years to complete.

Solvay Process is a pioneer producer of alkali products, and started the first manufacture of soda ash by the ammonia-soda process in the U. S. in 1884 in the present village of Solvay.

Yardney Electric A New Sustaining Member

Yardney Electric Corporation, 105 Chambers Street, New York City, is a rapidly expanding concern devoted to the exploitation of the Yardney Silvercel,* the silver-zinc storage battery which has made possible applications and equipment heretofore impossible of achievement. It is unequaled and irreplaceable for applications in which light weight and small volume are prerequisites. A new type of separator, developed under the auspices of the Yardney organization and utilizing new principles of ion exchange, has contributed toward a substantial improvement in the characteristics of the Yardney Silvercel.

Yardney Electric Corporation is the U. S. licensee of Yardney International Corporation, the headquarters for which is also located in New York City. The latter concern has numerous affiliated laboratories scattered over the globe and manned by outstanding scientists and engineers. From Sweden, England, France, Germany, and many other countries come information and theories on how to improve the silver cell, as well as suggestions on new and different fields of application.

Michel N. Yardney is President of Yardney Electric Corporation, Martin E. Kagan is Vice-President, and Dr. Paul L. Howard, Technical Director. Staffed by a large and carefully selected group of scientists, engineers, and technical personnel, this firm works around the clock toward constant improvement of their product.

Yardney Laboratories, Inc., of New York City, an affiliate of Yardney Electric Corp., has been concerned with the perfecting of the Yardney Silvercel.

Frank Solomon, Chief, Research Department, is an active member of The Electrochemical Society. Dr. Howard, formerly associated with the National Bureau of Standards, organized the Washington Section of the Society some years ago, prior to joining the staff of Yardney Electric Corporation.

* Trade Mark.

CORRECTION

The price of the *Corrosion Handbook*, edited by H. H. Uhlig and sponsored by the Corrosion Division of The Electrochemical Society, is $13.50. Published by John Wiley & Sons, Inc., New York. The price was incorrectly given as $12.00 in the company's advertisement in the October JOURNAL.

Industrial Cleaning With Ultrasonics

A new industrial sound that can't be heard is attracting notice in industry, according to George E. Henry, of the General Electric Engineering Laboratory, Schenectady, N. Y.

Speaking at Owensboro, Kentucky, before local chapters of the Institute of Radio Engineers, Mr. Henry said that high-power ultrasonics, or inaudible sound waves, is offering the best means yet devised for industrial cleaning of small parts.

"By directing the high-pitched sound waves through a liquid solvent into tiny corners and crevices of small machine-parts, the cleaning action of the solvent is more effective in removing dirt, grease, lapping compound and metal particles than any other method," he said.

The new cleaning method is not limited to small parts, such as watch parts, electric shaver heads, etc., and the only remaining question, Mr. Henry said, is how far the method can be extended to include different kinds of parts, and how large a proportion of the total metal-cleaning business can be profitably handled with ultrasonics.

Gould Batteries Opens New Plant at Kankakee

Gould National Batteries, Inc., Depew, N. Y., have started operations in their new plant at Kankakee, Illinois, located about 60 miles south of Chicago. This addition of 200,000 square feet of floor space was erected at a cost of $3,000,000 and will employ 300 people. The plant will increase the company's production about 20 per cent. Both automobile and industrial storage batteries will be made for civilian and military purposes. O. W. S

Division News Reported at Fall Meeting

Battery Division

E. F. Willihnganz of Gould National Batteries was unanimously elected *Chairman* of the Battery Division at the business meeting following a luncheon held at the Sheraton-Mt. Royal Hotel during the October meeting of the Society in Montreal. Others elected for two-year terms were N. C. Cahoon, *Vice-Chairman;* E. J. Ritchie, *Secretary-Treasurer;* and A. F. Daniel and U. B. Thomas, *Members-at-Large of the Executive Committee.*

The Secretary-Treasurer reported that the present membership is 249, with 18 members added and 7 lost during the year.

A report was made of the year's activities of the Division. Following two very successful Round-Table Discussions held in Detroit, efforts were concentrated on the preparation of material for two special issues of the JOURNAL. The August issue carried thirty pages of feature articles covering all the primary battery systems of current importance, a Technical Review and five original technical papers in the field of "Primary Batteries." Seven hundred additional copies of this issue were printed and are already sold out. Advertising income for August was $2010.38, the highest for any issue of the JOURNAL yet published.

The September issue covered "Storage Batteries" in much the same manner; it contained nine special articles, five of which covered various forms of the lead-acid battery. The other four articles described nickel-cadmium, nickel-iron, and silver-zinc alkaline batteries. Five hundred extra copies were printed, of which only about one hundred remain unsold. Advertising income for this issue was $1273.24, second only to that for August.

It was pointed out that the income from special advertising and the sale of extra copies of the two issues sponsored by the Division would result in a profit to the JOURNAL of over $3000.

The retiring chairman, J. N. Mrgudich, thanked the members for their help in preparing these issues and their support for the advertising program. Dr. Cahoon and Dr. Willihnganz listed the principal contributors and reviewers whose combined efforts had made the special issues possible.

Dr. Mrgudich turned the chair over to Dr. Willihnganz, who thanked the former chairman on behalf of the Division and expressed the hope that its future would live up to the promise implied by its first five years.

U. B. THOMAS,
Secretary-Treasurer (1952)

Electrodeposition Division

The Electrodeposition Division held its annual business meeting at Montreal on October 28. Chairman R. A. Wooffter presented a communication from American Society for Testing Materials Committee B-8, which suggested that the

Electrodeposition Division join in designating mils and microns as the official method of describing plating thickness. This suggestion was adopted.

Editor-in-Chief Allen Gray reported on the progress of the new edition of *Modern Electroplating*. Publication is expected during the first half of 1953.

F. A. Lowenheim raised the question of the desirability of more complete publication of discussions of technical papers. This matter was examined at length. A motion that the Division discontinue recording discussion at the meetings was defeated. The issue was finally settled by adoption of a motion that the present system of recording discussion be continued.

Nominating Committee Chairman E. J. Smith reported the following nominations:

Chairman—M. L. Holt
Vice-Chairman—C. A. Snavely
Secretary-Treasurer—Sidney Barnartt

The nominations were approved and all were elected by a unanimous ballot. Dr. Holt then assumed the chair and requested that any ideas for symposia or round-table subjects for the next fall meeting be communicated to him.

CLOYD A. SNAVELY, *Vice-Chairman*

Corrosion Division

On the technical program at the Montreal Meeting the Corrosion Division presented some 24 interesting papers at four sessions. Three additional papers were read by title only, owing to the absence of the authors. This was the largest group of corrosion papers presented to date, indicating the steady growth of the Division since its organization in 1942, just ten years ago. The quality of the papers was excellent and the attendance, interest, and discussions were noteworthy. Some of the papers made the headlines in the local newspapers.

At the business meeting of the Division, held on October 27, the following officers were elected for the coming year:

Chairman—Fred W. Fink
Vice-Chairman—W. D. Robertson
Secretary-Treasurer—Harold A. Robinson

Also, at this meeting, it was reported that the Corrosion Division had cooperated with the JOURNAL in the preparation of the Corrosion Issue in October, and with the effort to secure JOURNAL advertising.

During the year the Division participated in the activities of the Membership Committee and, at present, it has well over 500 members.

The Corrosion Handbook Committee reported that the Palladium Medal will be awarded again in the fall of 1953. The procedure for selecting the medallist has not been fully crystallized and the Committee will welcome any suggestions. Composing the Committee are F. W. Fink, Chairman of the Corrosion Division; H. H. Uhlig, Editor of the Corrosion Handbook; R. M. Burns, representative of the Advisory Committee of the Corrosion Handbook; and J. C. Warner, representative of the Board of Directors of the Society. This Committee has the responsible task of utilizing the profits from the *Corrosion Handbook* which have now increased to over $16,000. In addition to the Palladium Medal the Committee has been sponsoring a Prize Essay Contest which will be continued next year.

The next meeting of the Corrosion Division will be held in conjunction with the fall meeting of the Society at Wrightsville Beach, N. C., September 13–17, 1953. Here, the well-known corrosion testing facilities at Kure Beach will be open for inspection including the atmospheric tests in marine air, the total immersion tests in natural sea water, and the many indoor tests on sea-going metals. It is planned to hold the meetings of the Sea Horse Institute consecutively with those of this Society.

H. R. COPSON, *Chairman* (1952)

Electro-Organic Division

The meeting of the Electro-Organic Division, held in Montreal on October 28, was called to order by Hans Neumark at 10:00 A.M. The report of the Nominating Committee was received and on motion of Sherlock Swann, Jr., the following officers were elected unanimously:

Chairman—Christopher L. Wilson
Vice-Chairman—Harold M. Scholberg
Secretary-Treasurer—Stanley Wawzonek

The motion was made that the chairman appoint an editorial board to investigate the problem of publishing a monograph on electro-organic chemistry.

H. M. Scholberg reported that preliminary arrangements for a symposium to be held at the New York Meeting had been started. It was suggested that a round table also be held at the New York Meeting on the subjects: "Anodic Reactions" and "The Kolbe Synthesis."

HAROLD M. SCHOLBERG, *Vice-Chairman*

SECTION NEWS

Chicago Section

Joseph J. Katz, who is one of the country's foremost authorities on the subject of uranium chemistry, spoke to the Chicago Section at the November 7 meeting, on the design of nuclear reactors.

Dr. Katz described the various types including piles, breeder reactors, and homogeneous reactors. He discussed the applications of these units for generation of power, research, and the production of fissionable materials. Dr. Katz concluded his talk by giving his opinion on the immediate potential application of atomic energy.

R. R. BANKS, *Secretary*

Cleveland Section

Dr. D. M. Wroughton, Manager of the Chemistry Development Department, Westinghouse Atomic Power Division, Pittsburgh, was one of the speakers at the November 11 meeting of the Section, his subject the experimental phases of "Levitation and Melting of Metals with High Frequency." He described the developments which led to the high frequency coils used at present for suspending and melting metals by the eddy currents produced by the coils. The talk was enhanced by a movie which showed how the metal was introduced between the coils, how it melted, and how it was drawn off.

Dr. G. Comenetz, Advisory Engineer at the Westinghouse Research Laboratories, spoke on the theoretical phases of the process. From his formulas one can determine the best size of the metal used, the current requirements, and also the effect of changes in other parameters.

The after-dinner speaker was Mr. D. W. Hutchings, a Fulbright Fellow at Oberlin College, who spoke on the early history of electrochemistry. Mr. Hutchings was the second prize winner of the Prize Essay Contest of the Society.

J. M. MARGOLIS, *Secretary*

Midland Section

At the November 13 meeting of the Midland Section Mr. O. W. Simmons, of Frankford Arsenal, Philadelphia, addressed the group on "Titanium Developments." Mr. Simmons described the "skull" melting technique which he pioneered. In the "skull" technique the metal is arc melted in a crucible consisting of the metal being melted; the crucible walls are maintained by having them

in contact with water-cooled copper surfaces.

Mr. Simmons illustrated his talk with an interesting color film which showed the operation of a furnace for melting titanium and subsequent casting into graphite molds.

The methods described gave the following advantages: alloy castings free of dissolved carbon, castings free of tungsten inclusions, and the ability to remelt scrap.

F. N. ALQUIST, *Secretary-Treasurer*

New York Metropolitan Section

The New York Metropolitan Section held a President's Night on November 19 at which Dr. J. C. Warner was the featured speaker. The meeting was also favored by the presence of the Society's most recently elected honorary member, Dr. William Blum.

Dr. Warner explained that since his recent administrative duties had taken him away from his first love, teaching, he chose to speak on a strictly scientific rather than a more general or philosophical subject. He then proceeded to review the development of theories of solutions which have culminated in the Debye Hückel-Onsager treatment. The speaker's presentation was at all times clear and concise and he managed in a very limited time to give an excellent review of this most important subject.

In keeping with the tradition of the Section in welcoming guest speakers who are also good friends, the talk was illustrated by a surprise lantern slide or two. The usual lively discussion followed the formal meeting.

F. A. LOWENHEIM, *Secretary*

Philadelphia Section

The Philadelphia Section held its first meeting of the current season on November 5 at the University of Pennsylvania, and the fifty or sixty members and guests in attendance enjoyed an interesting program presented by the Department of Metallurgy of the University, under Dr. Robert M. Brick, Director. Preceding the meeting, the members and guests had an opportunity to meet Dr. Brick and his associates at an enjoyable informal dinner. Following a brief talk by Dr. Brick describing the research in his department, the meeting group visited the metallurgical laboratories where Dr. F. J. Dunkerley, Dr. N. Brown, and Mr. F. L. Vogel assisted Dr. Brick in giving the visitors informal descriptions of the projects and showing them the experimental apparatus used.

The Section chairman, Dr. John F. Gall, opened the meeting with a word of welcome and gave a brief report of his very favorable impressions of the Montreal meeting. Dr. Gall urged those who are qualified to join our Society and thereby to avail themselves of the benefits of membership. The program chairman, Dr. J. Fred Hazel, reported on the plans for the forthcoming Section meetings. Dr. Gall introduced the speaker of the evening, Dr. Brick.

Dr. Brick reviewed three projects currently under way in his department. He described the first as a study of the equilibria of molten iron with sulfur and oxygen. Dr. Brick indicated the importance of the study in relation to the problem faced in this nation with rising content of sulfur in the raw materials of

ROBERT M. BRICK

steel manufacture. He described the procedure in equilibrating molten iron with sulfur dioxide and argon, and the analytical means for determining sulfur in the equilibrium iron solution. The latter is accomplished by melting the sulfur-bearing iron with tin to produce a low-melting, easily handled liquid over which is passed pure, dry hydrogen to remove the sulfur.

The second subject was a discussion of ordering in copper-zinc alloys. Dr. Brick pointed out that despite the adjacency of copper and zinc in the periodic table and their similar atomic size, they form various phases as a function of electron concentration ratios. A description was given of ordering in solid solution, and the effect of ordering on the specific heat vs. temperature curve. The specific heat curve for beta-brass was shown, and later the guests were given the opportunity of examining the apparatus for continuous measurement of specific heat with temperature. Among other methods, Dr. Brick mentioned plastic deformation as a means for studying ordered metallic structures.

The last subject concerned the very interesting and important properties of iron at low temperatures. Several specific instances of catastrophic ship failures were mentioned to show the great importance of this topic. Ships have literally split in two as a result of brittle failure of the steel under severe winter conditions. Dr. Brick showed slides of critical shear stress as a function of temperature, down to liquid air temperatures, and related such data to planes of slip. He emphasized the role of basic information, on which the laboratory is working, in the solution of the very practical problems of ship failures.

(The abstract of Dr. Brick's talk appearing above was prepared by Mr. Edward Korostoff.)

E. L. ECKFELDT, *Secretary*

Washington-Baltimore Section

Dr. Karl Sollner, of the National Institute of Arthritic and Metabolic Diseases, gave a very interesting talk on "The Electrochemistry of Ion Exchange Membranes" at the November 20 meeting of the Section. The basic theories of the subject were summarized and the laboratory methods of investigating the subject were presented along with Dr. Sollner's findings. Of particular interest was the method of preparing membranes for study. Earlier work had been handicapped by a lack of membranes suitable for this type of work. Also of interest were the practical uses for membranes of high ionic selectivity, e.g., in purifying and concentrating processes and in electrodialysis.

The talk was followed by an informal discussion.

FIELDING OGBURN, *Secretary-Treasurer*

India Section

A technical meeting of the India Section was held on November 29 at the Central Electrochemical Research Institute, Karaikudi.

The program included a paper by Dr. T. L. Rama Char on "Some Aspects of the Electrodeposition of Cadmium." This was followed by tea and a visit to Central Electrochemical Research Institute at Karaikudi.

At the Section meeting held on August 4, 1952, a suggestion was made by Dr. B. K. Ram Prasad, past chairman, that a symposium on "Electrolytic Alkali-Chlorine" might be arranged under the auspices of the India Section to discuss the latest developments in the types of cells, utilization of chlorine, etc. This was welcomed by all the members present. It could, perhaps, be conveniently arranged in February 1953 at the time when the Indian Institute of

Metals is holding its annual meeting at Bangalore; then a goodly gathering of electrochemists and electrometallurgists is expected. In order to enable the Secretary-Treasurer to pursue the matter, members and patrons are requested to notify him at an early date as to whether they will be in a position to participate in the symposium and, if so, to indicate the subject on which they plan to speak. Any other views of members and patrons in this connection will be welcome.

The fourth *Bulletin of the India Section*, Number 4, Volume I, October 1952, has been published.

The Secretary is pleased to state that the following firms have become Patrons of the India Section:

1. Indian Telephone Industries Ltd., Durvaninagar, Bangalore District.
2. The Standard Batteries, Ltd., Bombay.

J. BALACHANDRA, *Secretary-Treasurer*

PERSONALS

EDWARD ORBAN of Monsanto Chemical Company's Mound Laboratory has been appointed chief of the technical information service of the research division.

Z. W. POKVITIS, chief metallurgist of Avildsen Tools & Machinery Inc., Chicago, has been appointed Director of Research. He was previously with a division of the company, Federal Drill & Tool Division, in New York.

C. ROGERS MCCULLOUGH, Director of Monsanto Chemical Company's atomic-electric project since June 1951, returned to the company's General Development and Patent Department on November 1.

SHERWOOD B. SEELEY has been promoted to the position of Technical Director of the Joseph Dixon Crucible Company, Jersey City, N. J. Mr. Seeley was formerly Director of Research.

ROBERT D. SCHWARTZ is now employed by the Shell Oil Company, Houston, Texas, as research chemist in their Exploration and Production Research Laboratory.

S. D. GOKHALE of Bombay, India, is now at the University of Tubingen, in Germany, for advanced study in electrochemistry.

GEORGE T. PAUL, formerly of the Department of Chemical Engineering, Princeton University, is now with the Calco Chemical Division, American Cyanamid Company, Bound Brook, N. J.

J. C. Warner Awarded AIC Gold Medal

J. C. Warner, President of Carnegie Institute of Technology and Electrochemical Society President, has been named the recipient of the Gold Medal of the American Institute of Chemists. The medal will be presented to Dr. Warner at the annual AIC meeting in Philadelphia in May 1953. It was awarded for "noteworthy and outstanding service to the science of chemistry and the profession of chemist, as a scientist of note, an educator for many years, president of an educational institute of high standing, and one who has long had the professional interests of chemists and chemical engineers at heart."

NEW MEMBERS

In November 1952, the following were elected to membership in The Electrochemical Society:

Active Members

ARTHUR BLOOMBERG, Chemical Construction Corp., P. O. Box 89, Linden, N. J. (Corrosion)

WILLIAM BRESNICK, The Glenn L. Martin Company, mailing add: 103 N. Stuart St., Baltimore, Md. (Electrodeposition)

EDGAR S. BYRON, Westinghouse Electric Corp., mailing add: 57 Collins Ave., Bloomfield, N. J. (Corrosion, Electrodeposition, and Electronics)

JOHN A. CONNOR, Leeds & Northrup Company, mailing add: 1910 A Humphrey Merry Way, Elkins Pk., Philadelphia, Pa. (Electric Insulation)

HAROLD G. DE HART, Irvington Smelting & Refining Works, 374 Nye Ave., Irvington, N. J. (Electrodeposition)

EDWIN T. GOODRIDGE, Horizons Incorporated, mailing add: P. O. Box 255, Princeton, N. J. (Electrodeposition)

SCOTT B. KILNER, Aerojet Engineering Corporation, Azusa, Calif. (Battery)

R. S. RAMACHANDRAN, The Indian Aluminium Co., Ltd., Alupuram, Alwaye, S. I. Rly, India (Corrosion, Electrodeposition, Electrothermic, Industrial Electrolytic, and Theoretical Electrochemistry)

CHARLES L. SCHEER, Foote Mineral Company, mailing add: 243 Hathaway Lane, Havertown, Pa. (Electrothermic)

ROBERT P. STAMBAUGH, National Car-

MANUSCRIPTS FOR NEW YORK MEETING

Triplicate copies of manuscripts or abstracts (not to exceed 75 words in length) to be considered for the Spring Meeting must be in the Secretary's office, 235 West 102nd Street, New York 25, N. Y., not later than *February 1, 1953*.

The dates of the Spring Meeting, which will be held in New York City, are April 12 to 16. Scheduled symposia will be: Electric Insulation; Electronics—Luminescence, Screen Applications, and Semiconductors; Electrothermics; and Theoretical Electrochemistry.

bon Company, Niagara Falls, N. Y. (Industrial Electrolytic)

Associate Member

K. K. CHERIAN, Indian Aluminium Co., Ltd., mailing add: % Film Distributing Co., Ennakulam, S. India (Corrosion, Electrodeposition, Electrothermic, Industrial Electrolytic, and Theoretical Electrochemistry)

Student Associate Members

DONALD W. ERNST, University of Wisconsin, mailing add: 2408 W. Auer Ave., Milwaukee, Wis. (Electrodeposition)

ERIC RAU, New York University, mailing add: 78–02 Kneeland Ave., Elmhurst, L. I., N. Y. (Corrosion)

LETTER TO THE EDITOR

More on Electrolytic Titanium

Dear Sir:

We have been much interested in the letter by Drs. Brenner and Senderoff on "Electrolytic Titanium" which appeared in the August 1952 number of the JOURNAL. For some time, work in this Department has been concerned with the electrolytic production of titanium, and a preliminary account of a method which produces titanium powder appeared in the September 1951 issue of the *Australian Journal of Applied Science*.[1]

It may be of interest to summarize the main features of the method. The electrolyte was a solution (8 mole per cent) of $TiCl_3$ in the eutectic mixture of KCl and LiCl. The Pyrex glass cell contained tungsten electrodes in separate cathode and anode compartments. Electrolysis was carried out under an atmosphere of purified hydrogen generally at a temperature of 550°C. The product was a powder which, judged from measurements of lattice parameter and micro hardness, was comparable in purity with that produced by the Kroll process, and, although somewhat finer, of a particle size and shape similar to that shown in Fig. 2 of Brenner and Senderoff's communication.

The KCl-LiCl eutectic was chosen as the base electrolyte because of its low melting point, which it was hoped would tend to reduce the possibilities of contamination from the cell and electrodes which were made from Pyrex glass and tungsten respectively. Even at a relatively low temperature of 550°C, however, these materials slowly contaminate the electrolyte.

The problems in the electrolytic production of titanium of adequate purity are of two types: first, the preparation of pure electrolytes, free from oxygen and other elements which can react with titanium; and, second, the development of materials resistant to attack by the molten salt mixture and anode gases. We have avoided the use of graphite for fear of pickup of carbon by the metal. There is a wide range of relatively low melting salt mixtures which could possibly serve as suitable electrolytes, and some of these are being investigated on a laboratory scale in this Department.

We agree with Brenner and Senderoff's conclusion, that "the prospects for the production of pure titanium powder by electrolytic means are good" and endorse their plea for publication of results so that it will be possible to assess on a scientific basis the advantages and disadvantages of electrolytic methods for titanium production.

HOWARD K. WORNER
G. M. WILLIS
HILL W. WORNER
University of Melbourne, Victoria, Australia.

[1] G. D. P. CORDNER AND H. W. WORNER, *Australian J. Appl. Sci.*, **2**, 358 (1951). Abstracted in: *Metals Rev.*, **25**, 23-C (1952); *Met. Abs.*, **19**, 668 (1952); *Chem. Abs.*, **46**, 4927 (1952).

BOOK REVIEW

ELECTROCHEMICAL DATA by B. E. Conway. Published by Elsevier Publishing Company, Amsterdam, Houston, London, New York, 1952. xx plus 374 pages, $8.75.

All electrochemists have cause to be grateful to Dr. Conway, Research Chemist at the Chester Beatty Research Institute, London, for collecting between one set of covers so much basic electrochemical data. He appears generally to have used intelligent discrimination in the selection of the best quantitative information available and has presented it in the form of a series of more than 300 tables.

The range of subject matter is very broad; we find values for universal constants, tables of data on the properties of colloids and macromolecules of biological importance, conductivities and potentials in fused salts, and parameters of electrode reaction kinetics, as well as the more usual compilations of conductances, standard electrode potentials, and transport numbers.

The author is meticulous in giving references to original sources and his extensive bibliography may be almost as useful as the data themselves. Whenever possible he states the precision of the values given and in many cases indicates the experimental or theoretical method by which they were obtained.

Fine Arrangement of Data

The book is well organized, beginning with universal constants and general physical properties, progressing through the thermodynamics of solutions to ionic transport. The author then deals with the electric double layer at interfaces. After a diversion into the field of fused and solid ionic conductors, Dr. Conway returns to the logical order with a chapter on reversible electrode reactions. The concluding section, of which Dr. J. O'M. Bockris is author, is an attempt for perhaps the first time to collect data on electrode kinetics, giving tables of the Tafel parameters for such reactions as have been carefully studied up to now. Most of the material deals with hydrogen evolution but there are tables on the deposition of metals, redox processes and anode reactions such as the evolution of oxygen and the halogens. There is a 14-page index to provide ready reference to specific information.

The problem of selection of types of data for a book such as this must always require the author to make difficult decisions, particularly in the preparation of the first edition, but in general Dr. Conway's choices appear to this reviewer to have been happy ones. The emphasis is on fundamental data and no attempt has been made to make this a complete handbook of electrochemical engineering. There are no tables on electroplating or on electroprocessing. Occasionally in the field of applied electrochemistry the author seems to have gone astray. For example, included in a group of tables dealing with lead-acid storage batteries there is one giving the terminal voltage of a cell as a function of degree of discharge. Such data are purely empirical and valid only for specific conditions of cell design, acid strength, and temperature. Their inclusion here is misleading and implies a generality which the data do not possess.

In spite of its minor flaws, this book should become one of the most frequently used on the desk of the practicing electrochemist. The author and the publisher are to be congratulated.

U. B. THOMAS

POLARIZED LIGHT IN METALLOGRAPHY, edited by C. K. T. Conn and F. J. Bradshaw. Published by Academic Press Inc., New York. xi plus 130 pages, $3.80.

This book was prepared for the Optical Methods Sub-Committee of the British Iron and Steel Research Association, (B.I.S.R.A.), and is the first attempt to make available a comprehensive survey of polarized light in metallography. It consists of a number of articles by authorities in the fields of optics, metallurgy, and, according to the introduction, "fields somewhat remote from metallurgy." The method of compilation has drawbacks as well as advantages. One drawback is that continuity is difficult to achieve even with the best editorship. Another which applies particularly to the present case is that the point of view of the practicing metallographer who uses the microscope as a metallurgical tool could not easily be kept in mind throughout the text. There is a refreshing confession in the introduction that the authors do not at all times agree in their views.

A book of this sort has been much needed and the sponsors, editors, and contributors deserve commendation for pioneering in what is admittedly a difficult field. The subject is difficult because those who have a thorough understanding of, and particularly a strong interest in, the relevant advanced optical theory too seldom seem to rub shoulders with the metallographer. The latter, himself primarily a metallurgist, has his main contact with other metallurgists, with materials and design engineers, and with those physicists whose main concern is with the nonoptical properties of metals. Interest in the subject will doubtless grow with time; and with the recent introduction of special college courses in metallography the gap will presumably become narrowed. In passing, it may be worth while to remark that not all the sales organizations of manufacturers of metallurgical optical equipment realize fully what the professional metallographer is trying to do. He wants to use polarized light to gain better understanding of those very structures usually outside the standard class used for textbook illustration and elementary exposition.

The first three chapters of the book, dealing with optical theory, will undoubtedly be used mainly for reference, especially as most of the examples are drawn, necessarily perhaps, from mineralogy. The fourth chapter, on the examination of metal surfaces, will be that of most direct interest to metallographers and is well done. However, like a great deal of the rest of the book, the text is condensed. More actual and more detailed "case histories" accompanied by more micrographs would make the chapter much more valuable. Incidentally, the book as a whole could have used more profuse and larger scale illustration; it is realized that this would have added to its cost. It seems regrettable just the same that British austerity appears to have been reflected lately in so many otherwise excellent publications.

The remaining three chapters deal, respectively, with metallic inclusions, with ores, and with the significance of polarized light in the study of metals and ores. Remarks similar to those made about the fourth chapter on metal surfaces also apply here.

It is hoped that there will be not only succeeding editions of this book but that the production of other books in the field may be stimulated.

E. E. THOMAS

RECENT PATENTS

Selected for electrochemists by Fred W. Dodson, Chairman of the Patent Committee from the Official Gazette

August 26, 1952

Brennan, J. H., 2,608,482, Ferrochrome-Silicon-Aluminum Alloy

Varian, S. F., 2,608,529, Method of Uniting Parts by Electrodeposition

Kahn, M., 2,608,530, Electrodeposition of Metal Salts

Fox, A. L., 2,608,531, Electrolytic Preparation of Manganese Dioxide

Lawlor, F. E., 2,608,532, Photochlorination of Alkyl Aromatics with Liquid Chlorine

Conklin, W. C., 2,608,595, Force Fitted Case for Single Cells

White, J. E., 2,608,596, Battery Case and Terminal Post Construction

Shive, J. N., 2,608,611, Selenium Rectifier Including Tellurium and Method of Making It

September 2, 1952

Gray, R. D. Jr., and Paecht, W. A., 2,609,338, Electrodeposition of Cadmium-Tin Alloy

Passal, F., 2,609,339, Bright Copper Plating From Cyanide Baths

McMahon, R. E., and McMahon, E. F., 2,609,340, Corrosion Inhibitor for Heat Exchangers and the Like

Barsy, I. J., 2,609,406, Temperature-Responsive Device

Rowswell-S., P., 2,609,407, Secondary Galvanic Cells and Electrodes of Such Cells

Heise, G. W., and Fox, R. P., 2,609,408, Deferred Action Type Gas Depolarized Dry Cell Having Prolonged Shelf Life

Radeke, W. H., 2,609,409, Battery Cell Inspecting and Testing System

Quinn, F. R. 2,609,470, Resistance Materials and Elements

September 9, 1952

Thomson, F. X., 2,610,133, Processes of Brightening and Passivating Cadmium and Zinc

Eaton, S. E., 2,610,143, Method of Electropolishing; 2,610,144, Method of Electropolishing

Wilson, A. B., 2,610,145, Electroplating

Kompart, W. W., 2,610,146, Electroplating Apparatus for Moving Strip

Brown, J. R. C. Jr., 2,610,154, Luminescent Zinc Sulfide Phosphors and Method of Preparing Same

Skinner, R. E., and McIntyre, G. H., 2,610,217, Electric Enamel Furnace

Lang, K. A., 2,610,218, Induction Metal Melting Furnace

Yardeny, M. N., now by judicial change

See the

February Issue of the Journal

for the article

"The Chemical Shore"

(Cleveland-Northeast Ohio area)

the second of the new series of REGIONAL FEATURES which will appear throughout 1953 describing Electrochemical Industry in various sections of the world.

of name Yardney, M. N., 2,610,219, Rechargeable Battery

Brennan, J. B., 2,610,220, Storage Battery Electrode

Keller, C. L., 2,610,221, Indicating Vent Plug for Electric Storage Batteries

September 16, 1952

Saslaw, O., 2,610,386, Semiconductive Cell

Weber, V., and Kunzler, W. S., 2,610,984, Thermogenerator and Pilot Burner Assembly

Schumacher, E. A., 2,610,985, Acceleration of Vaporization of Chlorine in a Battery

Brister, P. M., 2,610,986, Liquid Recovery Apparatus

Betz, L., 2,610,987, Battery and Cable Carrier

Cade, P. J., and Shaw, B. E., 2,611,007, Temperature-Compensating Conductivity Cell

LITERATURE FROM INDUSTRY

ELECTROLYTIC ALKALINE DESCALING PROCESS. Technical bulletin describes how this company's alkaline electrolytic process for derusting of metals will accomplish effective and complete scale removal of metals by the use of periodic reverse current. It is also reported that the process produces a better surface for hard chromium plating. Enthone, Inc. P-93

LABORATORY APPARATUS. Sixteenth edition of "What's New for the Laboratory" has been published. This 16-page booklet features 27 items, including a high-speed projection type balance which can also be used for analytical work; a device for trapping mercury blown from manometers; a surface temperature thermometer; two-stage vacuum pump; microscope with built-in illuminator, etc. Scientific Glass Apparatus Co. Inc. P-94

X-RAY TROUBLE CHART. New 11 x 15 in. chart titled "Locating Common Electrical Faults in X-Ray Generators" lists symptoms, suspected location, trouble possibilities, and methods for locating and correcting generator troubles common to all makes of X-ray generator equipment. North American Philips Co., Inc. P-95

CASTING RESINS. A new industrial technique—embedding electrical components in "Scotchcast" brand electrical insulating resins—is described in an 8-page, illustrated booklet. Outstanding properties—moisture resistance, dielectric strength, adhesion, etc.—shown in detail on technical data page. Minnesota Mining and Manufacturing Co. P-96

IMPEDANCE BRIDGES. Pamphlet describes new model impedance bridge and accessory amplifiers. Bridge combines features of exceptionally high accuracy, wide range, and compactness for precision measurements of resistors, capacitors, and inductors. Brown Electro-Measurement Corp. P-97

ORGANIC SILICOFLUORIDES. Data sheets are available on company's new line of products, the organic silicofluorides, which are now offered commercially. The Davison Chemical Corp. P-98

LABORATORY FURNACES. "Burrell 'Unit-Package' Box Muffle Furnaces" is the title of a 4-page bulletin describing a new line of laboratory furnaces for low and high temperature testing operations. Five different models are described and detailed information given. Burrell Corp. P-99

ELECTRIC HEAT. Illustrated leaflet describes design of a new immersion-type electric heating unit for electroplating baths. The heater has a thick lead sheath which resists corrosive acid action of copper, chrome, and nickel solutions—and offers many advantages over steam heating. Edwin L. Wiegand Co. P-100

ELECTRIC EYE. New bulletin describes the wide range of application of "electric eyes" directly to process industries. Usual and unusual installations covered, and standard and special instruments described. Ess Instrument Co. P-101

ELECTRICAL EQUIPMENT FOR CHEMICAL PROCESSING. A 15-page booklet catalogues and describes electrical equipment for chemical processing. Divided into three main sections—power generation, distribution, and utilization—the booklet illustrates and explains the function of widely varied apparatus. Westinghouse Electric Corp. P-102

PRECISION TORQUE BALANCES. Literature is available on a line of precision torque balances manufactured in Holland and recently introduced into the U. S. Suitable for use in factories and laboratories. Available in a wide range; capacities from 1 milligram to 20 grams with sensitivities ranging from .002 milligram to .02 milligram. Ohaus Scale Corp. P-103

"THE LABORATORY." 40-page publication (Vol. 22, No. 1) just issued has "the latest developments in laboratory instrumentation and technique." Feature article gives the first account of the research behind the $300,000,000 industry where doughnuts are automatically made in 800-dozen-an-hour machines. Also, other features and instrumentation section. Fisher Scientific Co. P-104

To receive further information on any product or process listed here send inquiry, with key number, to JOURNAL of The Electrochemical Society, 235 West 102nd Street, New York 25, N. Y.

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Editorial

Productive Professional Activity

THE INDUSTRIAL activity in the Cleveland area, as detailed elsewhere in this issue, is evidence of the important part played by the scientist and engineer in our present economy. Yet there is grave concern in many quarters over the inadequacy of our present supply of technical personnel and the failure of our schools to furnish enough graduates to meet current needs, either in pure or applied science.

In the U. S. A. the present demand for graduates in engineering alone, we are told, is 30,000 per year and sharply rising. The supply, on the other hand, has now dropped from a peak of approximately 50,000 per year in 1949–50 to a level of 20,000, and is still declining. Perhaps some 4000 will graduate this year in chemical engineering, but of these only a very few will have had specialized training in electrochemistry. Undoubtedly an increase in our educational effort, in pure as well as in applied science, is needed to maintain our present rate of technological progress.

Nevertheless, it would be well to consider to what extent our present difficulty is due to inefficient utilization of our technical resources rather than to extreme shortages of adequately trained personnel. Many of our technical graduates—estimates run as high as 50 per cent—are not immediately available for professional employment, chiefly because of military service requirements. Although this tends to aggravate the immediate shortage, a permanent loss to the profession is not involved. More serious, and perhaps equally difficult to avoid, is the waste of man-power due to duplication in government and academic work and in industrial competitive effort.

Perhaps the greatest gains might accrue from efforts to reduce to a minimum the diversion of scientists and engineers to other than technical work in their fields of specialization. Less than ten per cent of our chemical engineers are reported as engaged in the work of design, construction, and installation. The records of engineering societies indicate that more than thirty per cent of their members are in executive or administrative positions. Employment prospectuses emphasize the opportunities for advancement in terms of promotion in the corporate organizations; technical schools point with pride to their illustrious alumni who have become business executives; far too often even the young graduate considers his profession as a stepping-stone to material success rather than as a career in itself.

No doubt greater recognition of technical achievement will be required to attract and hold career men. Meanwhile, it is the problem of the employer, the school, and of the technical man himself to demonstrate the possibility of achieving a successful and intellectually satisfying career without departure from the level of productive professional activity. Perhaps it is in this direction, as well as in the promotion of electrochemical education, that the Society can exert its influence to advantage.

—G.W.H.

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All standard types and sizes plus full facilities for the engineering and production of special anodes for practically any requirement.

Stackpole Carbon Company . . . St. Marys, Pa.

STACKPOLE

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THE CHEMICAL SHORE

. . . *product of a giant chain reaction in the Cleveland-Northeast Ohio area*

Robert C. Hienton

We don't know who coined the name. It just seemed to "happen." But once introduced, it spread through the chemical industry like wildfire.

Everyone suddenly knew of The Chemical Shore, the 30-mile stretch of Lake Erie shoreline between Fairport and Ashtabula in Northeast Ohio. Since V-J Day, it has become one of the world's great chemical centers. To understand why The Shore has grown with such whopping strides, let's look first at the entire Cleveland-Northeast Ohio region, or as we call it, "The Best Location in the Nation." It extends for 100 miles along the southern shore of Lake Erie from the Ohio-Pennsylvania line to the village of Avon Lake, 20 miles west of Cleveland.

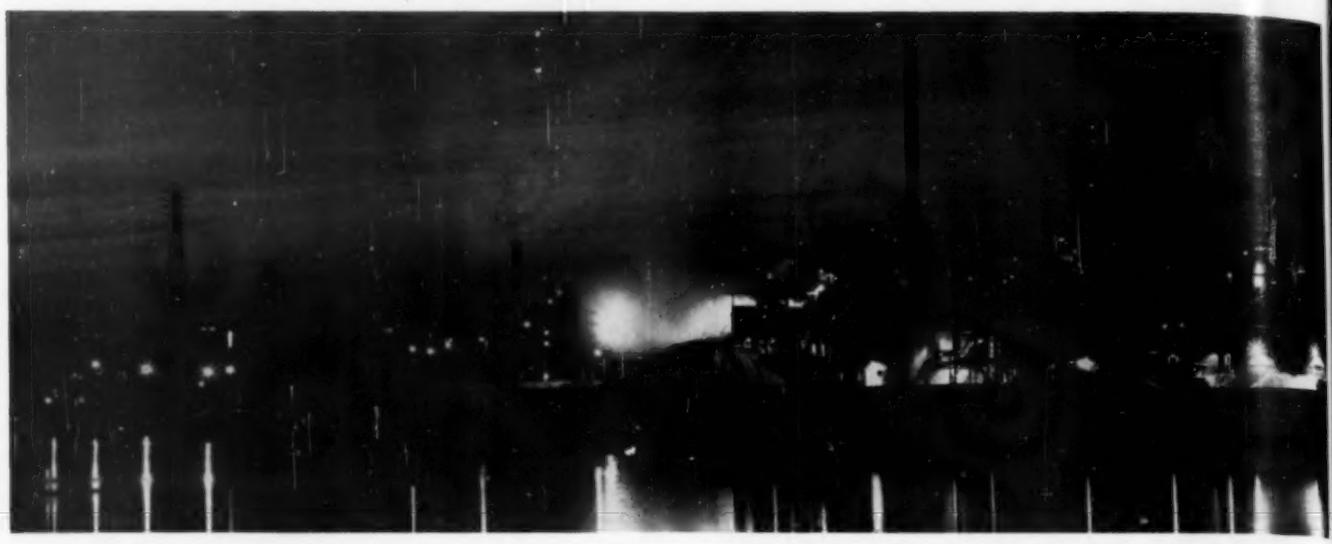
The nerve center of this 1700-square mile area is Cleveland —seventh largest city in the United States and one of the nation's busiest and fastest growing metropolitan areas. The area's tremendous productivity depends upon many things—its natural resources, its manpower, its markets, its transportation network—but most of all, the area runs on electric power. As supplier of that power, The Cleveland Electric Illuminating Company has a deep interest in the area's development. We sincerely believe it is the "best location" for many firms and we consider the electrochemical industry one of our blue-chip growth industries.

During the past seven years, American industry has committed more than *$1.5 billion* for widely diversified expansion in Cleveland-Northeast Ohio. This is more than three per cent of the nation's total, yet the region contains only one per cent of the nation's population. The steel industry has just completed a 50 per cent expansion in productive capacity. Cleveland today makes eight to ten per cent of all American-made steel strip, sheet, and plate. Approximately 8 per cent of the nation's wire drawing is done in Cleveland. There are now

ROBERT C. HIENTON

Manager of Marketing,
The Cleveland Electric
Illuminating Company,
Cleveland, Ohio

The Eastlake power plant of The Cleveland Electric Illuminating Company will be one of the world's largest, with an ultimate capacity of one million kilowatts. When finished, the plant will cost more than $100 million.



The Cleveland Works of the Du Pont Company's Grasselli Chemicals Department silhouetted against the sky, with the sulfuric acid unit making a background for the illuminated sulfur pile.

3500 manufacturing companies here. Brief as that over-all picture is, it will give some idea of this area's vast industrial expansion during the last seven years.

Of the $1½ billion invested in the area since the end of World War II, the chemical industry has accounted for more than $235 million, or 15.3 per cent of the total. More than half of this amount has been declared since the outbreak of the Korean war. This huge investment by the top names in the industry has set off a giant chain reaction.

When producers of basic chemical supplies, such as Diamond Alkali and the Electro-Metallurgical Division of Union Carbide and Carbon Corporation, built multimillion dollar plants in the Cleveland-Northeast Ohio area, satellite industries moved in quickly to process the output of the basic chemical producers.

Raw Materials

The trigger for this giant chain reaction is the area itself. It is rich in the natural resources which the chemical industry requires.

Salt.—Along the Lake Erie shore, at an average depth of 2000 feet, are from 150,000 to 200,000 tons of rock salt per acre. Natural brines of magnesium and bromine are found both above and below the salt stratum. This huge resource is all the more valuable because of the unlimited supply of raw water nearby.

Water.—In Lake Erie, chemical producers have an unlimited supply of raw water for processing and plant uses. The lake is one of the few remaining sources of good quality water which can be obtained at an economical cost. The average water temperature is 51.5°F with a minimum of 33°F in the winter months. During July and August, the probable maximum is 80°F, depending upon the depth at which water is taken from the lake. Readings of lake water temperatures indicate stratification of water in the lake, especially during the summer months. Evidence indicates that it will be possible to get an unlimited supply of extremely cool water by running a submerged intake out to a 50-foot depth in the lake. This is of major importance during the summer months when cooler water can reduce, to a considerable degree, the number of condensers needed.

One of the key factors in the decision of the National Distillers Chemical Corporation to build in The Illuminating Company's service area was that ultimately National Distillers may need *more than 10 million gallons of water per day.* The chemical analysis of Lake Erie is as follows:

	Parts per million
Alkalinity (in terms of $CaCO_3$)	85.0
Permanent hardness (in terms of $CaCO_3$)	29.0
Total hardness	114.0
Calcium (Ca)	34.1
Magnesium (Mg)	8.6
Iron (Fe)	0.24
Silica (SiO_2)	3.1
Carbon dioxide (CO_2) free	3.1
Hydrogen ion concentration, *p*H	7.5

Silica.—The supply of silica in Northeast Ohio is virtually inexhaustible. Most of this vast deposit (estimated at 100 million tons) is in Geauga County, which is southeast of Cleveland. The deposit was left there by two prehistoric glacial systems. Mining operations are carried on in the county at Thompson and Chardon.

Limestone.—Limestone is readily available to chemical producers from the upper lakes and is delivered by lake carriers at low rates. Diamond Alkali brings in about 1½ million tons of limestone every year. Dolmitic limestones are obtained from the northwestern part of Ohio. At one time, the Ohio counties of Sandusky and Seneca produced more dead burned dolomite than all the rest of the United States combined.

Coal.—Coal for fuel and processing is available from 17 major coal beds within overnight hauling distance.

Oil.—Millions of barrels of oil are known to be in reserve in Ohio. More than half of this reserve is top grade Pennsylvania crude.

Soybeans.—Ohio has over a million acres of soybeans under cultivation.

Electric Power

The heart of any industry, and especially the electrochemical industry, is electric power.

For every two to three dollars spent on electrochemical facilities it may be figured that one dollar must be spent to enlarge power supply facilities. And the electrochemical industry grows almost unbelievably fast. Many segments of the

industry grow at a cumulative rate of eight to nine per cent per year.

To keep well ahead of industry's needs for electric power, The Cleveland Electric Illuminating Company is continuing a vast power expansion program which has been the largest—both from dollars invested and the number of people affected—of any company in the area.

Total investment in plant and property now exceeds $315 million. Investment in new facilities is speeding along at $2½ million a month. The Avon power plant now generates 420,000 kw. The Ashtabula power plant at the eastern end of the service area has a capacity of 240,000 kw. The Lake Shore power plant located in Cleveland has a generating capacity of 484,000 kw. All three plants are interconnected.

A fourth power station, at Eastlake, 20 miles east of Cleveland at the mouth of the Chagrin River is now being completed. Two 125,000-kw turbogenerators will go "on the line" next year, and a third 125,000-kw unit will be installed early in 1954. The fourth generator, a 208,000-kw unit, will be available for service by 1956. When the first section of the new plant is in operation, The Illuminating Company's total power capacity will be 1½ million kw—nearly double the system capacity of three years ago.

Markets

While electric power is the heart of the electrochemical industry, the continued growth of the industry depends upon chemical product markets. A chemical plant located in the Cleveland-Northeast Ohio area is in the heart of one of the largest, fastest-growing, and most diversified markets in America.

Metal fabricating industries.—As the steel and other metal fabricating industries expand, the demand for chemicals expands. Today production and fabrication of ferrous and nonferrous metals employ 75 per cent of the people working in Cleveland industry. This area's steel-making capacity is being expanded by 50 per cent, which is almost *three times* the present national rate of increase. As stated earlier in this article, Cleveland now produces eight to ten per cent of all American-made steel strip, sheet, and plate. Total cost of new steel-making capacity being added in the area will exceed $150 million, increasing Northeast Ohio's steel output 50 per cent. Republic Steel is currently putting $100 million back into this area with a huge expansion program which will build the world's largest strip mill, a 1400-ton blast furnace, and four open-hearth furnaces with a combined output of 1000 tons of steel per heat.

Paint manufacturers.—This area has frequently been called "the paint capital of the world." Almost 100 manufacturers of paints, varnish, and lacquer are located here, including: The Sherwin-Williams Company, The Glidden Company, The Patterson-Sargent Company, Arco Manufacturing Company, Ferbert Schorndorfer Company, and Forbes Finishes Division of Pittsburgh Plate Glass Company.

Rayon.—Two rayon producing plants are in the area.

Paper.—The area has two mills making paper, pulp, and paperboard. One is the Jaite Paper Company in Jaite, the other is the Chase Bag Company in Chagrin Falls. Thirty-three others are located in the state.

Plastics.—Fourteen plastics products producers are located here. The total for Ohio is 76.

Rubber products.—The area has 14 rubber products manufacturers; and nearby Akron, only 30 miles south of Cleveland, is the rubber center of America.

Fertilizers.—There are 37 plants producing fertilizer in Ohio. The American Agricultural Chemical Company, Stadler Products Company, and Swift & Company are all located in the Cleveland-Northeast Ohio area.

It is also interesting to note that more than two-thirds of all United States product classifications are produced in the "best location." Certainly most, if not all, of these product classifications depend upon the chemical industry in some way.

Transportation Services

Located at the market center of America, the Cleveland-Northeast Ohio area is also the heart of a great transportation network. Nine railroads serve the area, along with more than 150 motor truck lines. Nine airlines maintain regular flight schedules in and out of Cleveland, which could be of special importance to the chemical industry for speeding liaison work. Pipelines can also be classified as one of Northeast Ohio's important transportation mediums. A growing list of products

The Diamond Alkali Company's plant produces more than 150 different chemicals, using 100 million gallons of water per day.

EUGENE WAINER
Horizons Incorporated

A. O. THALACKER
Hooker-Detrex Corporaton

such as hydrogen chloride, chlorine, and acetylene are now being exchanged in the area by pipeline.

Coal transportation by pipeline will soon be a practical reality in Ohio according to representatives of the Pittsburgh Consolidation Coal Corporation. That company has already invested more than half a million dollars in the development of a coal-carrying pipeline. A three-mile line built by the company in the southern part of Ohio has been used experimentally during the past year. The line itself is made of 12 ¾-in. steel pipe. Before going into the line the coal is crushed to fine size. It is then mixed with water about 50–50 to form a slurry and pumped through the pipeline under pressure. It moves as readily as oil or gasoline. At the receiving end, the coal is separated from the water in a drying machine. The crushed coal is then ready for pulverizing and firing. As the water is clean it can be pumped into rivers or lakes. The 12 ¾-in. line, say the Pittsburgh Consolidation engineers, is big enough to pump through 7000 to 9000 tons of coal a day. That is 2½ million to 3 million tons a year. Needless to say, this experimental work is being watched with considerable interest, and it is believed that coal-carrying pipelines will be a cost-cutting reality within the very near future.

Low-cost water transportation to all Great Lakes ports is readily available. Approximately 80 per cent of the freighter fleet operating on the Great Lakes is controlled from the Cleveland area. Forty-one foreign ships maintain scheduled service between Cleveland and Europe and North Africa, via the St. Lawrence River. Northeast Ohio ports transship more iron ore than any other area in the world.

Of special importance is the 241-mile Ohio Turnpike, which will connect with the Pennsylvania Turnpike on the east and the Indiana State Line on the west. Construction was started October 1952, financed by a $326-million bond issue.

Plant Sites

Despite the area's unprecedented growth since V-J Day, Cleveland-Northeast Ohio has thousands of acres of land ideally suited for electrochemical development. This acreage is available in city, village, and rural areas, inland and lakefront, on main highways and railroads.

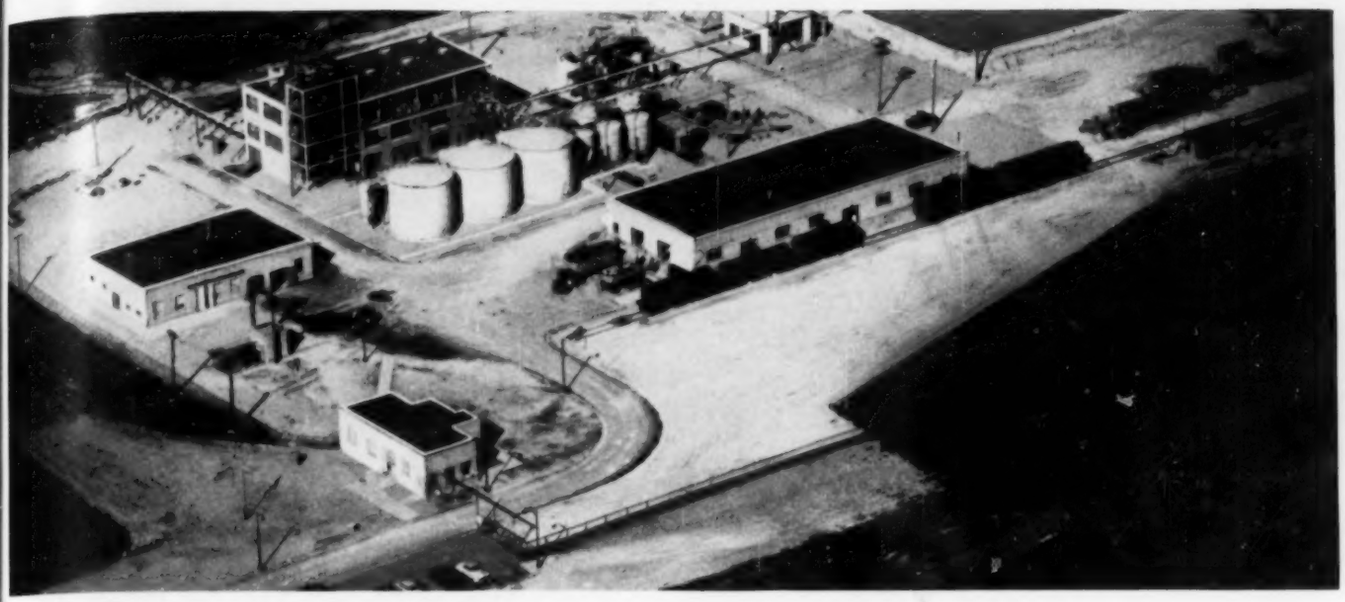
The area has virtually unlimited sites for new chemical plants on main lines of principal railroads. Chemical firms which rely on motor transportation can find many excellent sites along main trucking highways. Construction cost increases in the area since 1946 are below the average for the nation's 30 largest cities. Undeveloped land for large industry sites is priced between $350 and $1000 per acre. Water pumping is easy and cheap because of level land at lake's edge, 50 to 60 feet above water level. Because the area has a solid shale foundation about 40 feet below the surface, plant sites have excellent load-bearing characteristics.

The Illuminating Company recently purchased three sites, totaling 954 acres of farmland, in the heavily developed industrial area extending east of Painesville. This acreage which includes 5800 lineal feet of Lake Erie frontage was purchased for ultimate resale as industrial plant sites.

Within a five-mile radius of the site in Lake County are plants of Industrial Rayon Corporation, Diamond Alkali Company, A. E. Staley Manufacturing Company, Diamond Magnesium Company, the Naugatuck Chemical Division of the U. S. Rubber Company, and Stauffer Chemical Company —all of which have undertaken substantial expansions in the past two years.

The second site, in Ashtabula County, is located three miles east of The Illuminating Company's Ashtabula power plant and two miles east of the Union Carbide & Carbon properties, where the Electro-Metallurgical and Linde Air Products divi-

Laboratory of Horizons Incorporated, Cleveland, Ohio



Hooker-Detrex Corporation plant at Ashtabula, Ohio

sions are now spending over $35 million in post-Korea expansions. The third site is also in Ashtabula County, ½ mile south of the Illuminating Company's Ashtabula plant.

In the same general area, new plants were recently erected by National Distillers Chemical Corporation and by the Hooker-Detrex Company.

Labor Force

Northeast Ohio's labor force numbers about 700,000 workers. Less than half are presently employed in industry. By tradition, environment, school training, and by the very nature of the area's highly diversified industrial structure, the labor resources of Cleveland-Northeast Ohio rank with the best to be found in the world. The area has long been a center for the manufacture of precision products. Many generations of skilled workers and technical specialists have plied their trades here. The climate has had much to do with the heavy concentration of skilled and semiskilled personnel in this area.

Located on the southern shore of Lake Erie, The Chemical Shore is milder in the winter and cooler in the summer than many other areas at the same latitude. There are fewer extremes in temperature, yet the regular cycle of four seasons prevails. This combination provides the environmental conditions ideally suited for active, precise, highly-skilled work—the type of work typified by the chemical industry.

Cost of Living

The U. S. Bureau of Labor Statistics reports that it costs less to live in Cleveland than in 23 other major American cities. Cost of living varies considerably among the four counties of Northeast Ohio, with Cleveland generally above the four-county average.

Housing

Housing activity in Cleveland is extremely high. Reversing the trend in most other cities, the Cleveland building industry scored a 24-per cent increase in activity in the first quarter of 1952, compared with the first quarter of 1951. In 1951, the Cleveland construction industry had its second largest year in the area's history. Since 1946, more than 80,000 new dwelling units have been completed in the area, providing housing for over 100,000 workers.

Educational and Research Facilities

Ohio has more colleges than any other state in the Union. Many of these colleges are training scientists for the growing chemical industry. Some, such as Western Reserve University, Case Institute of Technology, and Fenn College, are closely allied with the chemical industry and conduct many research projects for them. Because of the nucleus formed by these and other institutions, the area is developing as one of the nation's great chemical research centers.

A recent addition was the B. F. Goodrich Company's main research and development laboratory where over 200 scientists are exploring rubber, plastics, and other chemical products.

The Diamond Alkali Company has just opened a new research center in Painesville. Others with research and development laboratories in the area are Harshaw, The Standard Oil Company of Ohio, Lubrizol, National Carbon, and the Brush Development Company.

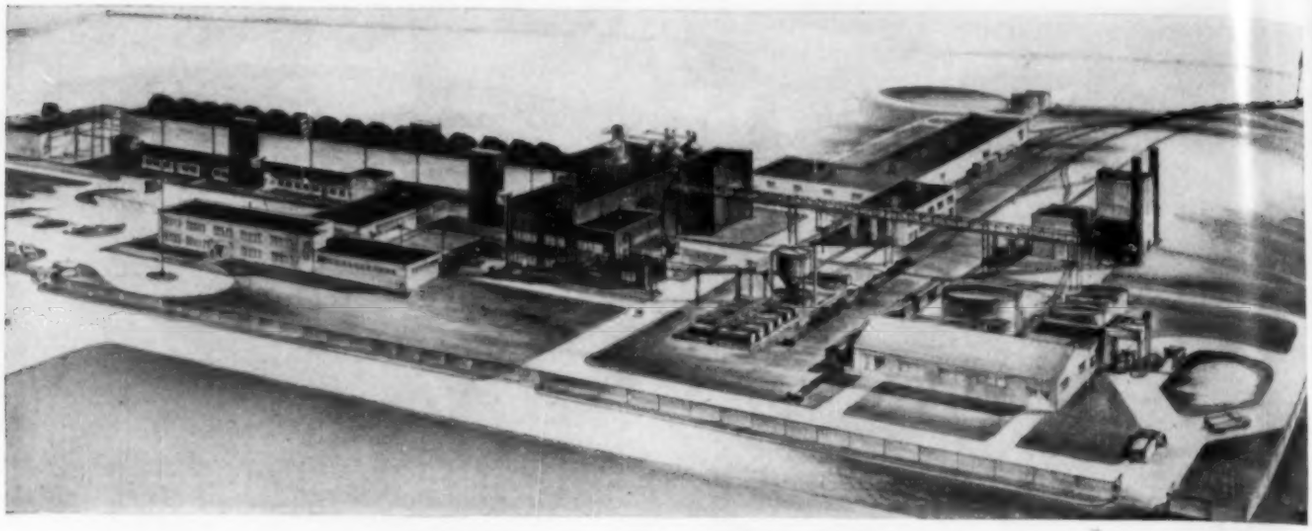
Horizons, Inc., a recent entrant in the titanium field, has a laboratory in this area. The Lewis Flight Propulsion Laboratory of N.A.C.A. has over 2500 scientists and technicians conducting research in a $66-million laboratory.

The Area's Growing Chemical Companies

Because of the many advantages the Cleveland-Northeast Ohio area offers the chemical industry, chemical companies which have already located here are constantly expanding. A cross section of their expansion offers striking evidence of faith in their industry and in this region.

The U. S. Rubber Company—Naugatuck Chemical Division

The Naugatuck Chemical Division of the U. S. Rubber Company acquired its plant site on The Chemical Shore in two moves. In 1949 it acquired title to the Glenn L. Martin Company's vinyl resin plant and one year later acquired adjacent property of the former Buel Metals Company. Recently, U. S. Rubber announced a $3,250,000 expansion program for the Naugatuck plant, which will double the plant's capacity of Marvinol polyvinyl resin. The latest expansion program, which is expected to be completed in January 1954,



National Distillers' plant, located at Ashtabula, Ohio

will boost the plant's resin production to more than 50 million pounds annually. Construction of seven new buildings is included in the project. In addition to expanding its resin capacity, the Naugatuck plant has been conducting an intensive research and development program aimed at new and more efficient types of vinyl resins for the plastics industry. The plant recently announced Marvinol VR-21, which offers the industry a resin having the processing characteristics of the copolymers but retains the superior properties inherent in straight polyvinyl chloride resins.

National Distillers Chemical Corporation

The National Distillers Chemical Corporation added another basic chemical plant to The Chemical Shore several years ago—their product, metallic sodium. Estimated daily capacity of the plant with all 94 Downs cells in operation is 100,000 lb of sodium and 154,000 lb of chlorine.

National Distillers produces its metallic sodium by electrolysis of fused sodium chloride. Crude sodium is further refined and cast in ingots or bricks and packed in drums for shipping. The molten sodium is drawn by vacuum into tank cars, allowed to cool and solidify, and is remelted before unloading. The low melting point (97.5°C), low specific gravity, high heat conductivity, and large scale uses of sodium make this shipping technique feasible.

The by-product is compressed and piped to the Hooker-Detrex Corporation for use in the manufacture of chlorinated solvents which find wide application in the metal degreasing and dry cleaning fields. The use of sodium hydride in the metal industry for descaling stainless steel and other special alloys makes the National Distillers' plant at Ashtabula especially valuable in this and adjacent steel producing areas. Sodium can be used in alloy formations with silver, gold, tin, mercury, cadmium, zinc, and lead, and is used in removal of antimony and bismuth from lead.

Grasselli Chemical Division of Du Pont

One of the area's old-line companies is the Grasselli Chemical Division of Du Pont. This plant has been a part of the community life of Cleveland for 85 years. The Grasselli Chemicals Company was purchased by Du Pont in 1928 and since 1936 has operated as one of the ten industrial departments of the Du Pont Company. The Grasselli plant produces acids and heavy chemicals that are basic to much of the nation's industry. It also manufactures a wide variety of agricultural chemicals for control of insects and plant diseases, disinfecting of seeds, and control of weeds and brush. The plant occupies 55 acres, produces 65 basic products, and serves 26 individual industries. Operations of the plant give jobs to 505 men and women. Du Pont has spent approximately $2 million in expansion and new facilities for the Grasselli plant since V-J Day.

The Standard Oil Company of Ohio

Two years ago, The Standard Oil Company of Ohio put into full production a new thermofor catalytic cracking unit with a capacity of 18,000 barrels of gasoline a day. Tall as a 22-story building, the new "cracker" contains two independent cracking units. The twin units operate simultaneously and continuously, but one can be shut down for inspection or repairs while the other stays in operation. Highest of all industrial structures in Ohio, the cat-cracker was erected at a cost of $4 million. Standard has been continually improving and increasing its facilities. It has spent over $25 million on new plants in Cleveland in the past several years.

General Electric Wire Works

An important firm in the Cleveland-Northeast Ohio area that may not be ordinarily considered a chemical company is the General Electric Wire Works, which produces the rare gases krypton and neon. The company also uses hydrogen obtained from the chlorine-caustic cells of the Columbia Chemical Company in Barberton, Ohio.

National Carbon Division of Union Carbide & Carbon Corporation

The National Carbon Division of Union Carbide and Carbon Corporation in our service area has the world's largest primary battery factory. National Carbon's research facilities, founded in 1902, cover all phases of primary batteries and carbon products. The company also researches motion picture optics, automobile antifreeze, and high polymer chemistry.

Electro-Metallurgical Division of Union Carbide & Carbon Corporation

The big "Electro-Met" plant located in Ashtabula on the eastern extremity of The Illuminating Company's service area produces ferroalloys and calcium carbide. It recently expanded to double its previous capacity. This plant is one

of the world's largest producers of calcium carbide, which is the basis for many acetylene hydrocarbon chemicals.

Linde Air Products Company

Linde Air Products Company is another division of Union Carbide and Carbon. It recently completed a $7-million tonnage oxygen plant to supply the major steel companies. When operating at full capacity, the plant will employ between 75 and 100 persons and will produce more than 100 million cubic feet of oxygen per month. The company also produces other industrial gases.

The Ferro Corporation

Ferro is the world's largest producer of porcelain enamel Frit, a high temperature fired enamel coating. It also produces large quantities of colors for ceramics, glass, and plastics. A Ferro subsidiary company in Bedford, Ohio, makes metallic soaps for the paint and varnish industry. Ferro besides being one of the world's top enamel coating producers has successfully branched into allied fields such as insecticides and titanium.

Sherwin-Williams Company

The Sherwin-Williams Company is the world's largest producer of paints, varnishes, and lacquers. The company's Cleveland plant produces many types of paints, including marine finishes and the famed "Kem-Tone." A Sherwin-Williams castor oil solvent extraction plant is also located in the Cleveland-Northeast Ohio area.

The Glidden Company

The Glidden Varnish Company, producers of Jap-a-Lac, was reorganized into the Glidden Company in 1917. Glidden has branched out into many fields, but still has its main paint and varnish plant in Cleveland.

Strong-Cobb and Company

Strong-Cobb is one of Cleveland's six pharmaceutical companies. It traces its founding to 1833, although it was not until 1888 that it entered its present lines. Today, Strong-Cobb is one of the nation's largest private formula houses and has made many contributions to the medical field through its extensive research facilities.

The Cleveland manufacturing plant of the Ohio Chemical and Surgical Equipment Company.

The Lubrizol Corporation

One of the area's fastest growing chemical plants is the Lubrizol Corporation in Wickliffe. It produces additive agents for lubricants and other products for the petroleum industry. This plant, which had a small beginning only 15 or 20 years ago, has expanded regularly to meet demand requirements for transmission and crankcase lubricants, cutting oils, and other petroleum products.

Diamond Alkali Company

The Chemical Shore was pioneered by the Diamond Alkali Company in 1912. It started by producing soda ash for glass manufacturing. Today, Diamond Alkali is the nation's second largest producer of basic alkali and related products. Although soda ash is still the company's number one product, it also makes large quantities of caustic soda, electrolytic chlorine, sodium bicarbonate, carbon tetrachloride, muriatic acid, chromates, cement, coke by-products, and alkali specialties. The Diamond Alkali plant now employs over 3500 workers who help produce over 150 different chemicals. It uses over 100 million gallons of water a day.

Research Laboratory and Edgewater plant of the National Carbon Company, located in Cleveland; the latter has the largest primary battery factory in the world.

Aerial view of plant of Harshaw Chemical Company, one of the 'Shore's' old-line companies, which produces numerous chemicals for a variety of uses.

Stauffer Chemical Company

Not far from Diamond Alkali is the $1½-million plant of the Stauffer Chemical Company. It produces carbon bisulfide which serves as a raw material for Diamond's carbon tetrachloride. Stauffer's carbon bisulfide also goes to Industrial Rayon's continuous spinning mill, which is in the neighborhood. Proof of the close integration of operations is found in the fact that Stauffer gets sulfur back from Diamond Alkali to be reburnt for more carbon bisulfide.

The Diamond Magnesium Company

The Diamond Magnesium Company, also located near Diamond Alkali, has a rated capacity of 18,000 tons of magnesium per year. This plant, which was constructed during World War II, is one of the most efficient magnesium installations in the United States.

Industrial Rayon Corporation

"Tyron" tire cord and fabrics are made in Industrial Rayon plants in Cleveland and Painesville. The Cleveland plant is one of the country's oldest sources of rayon. The Painesville plant houses a completely modern continuous process method for rayon production, which it developed and perfected.

B. F. Goodrich Chemical Company

Built in 1947 in Avon Lake on the far western side of The Illuminating Company's service system, the B. F. Goodrich Chemical Company has continually expanded to meet increasing demand for its chemical products. The plant itself is divided into five sections. The first section to be completed was the pilot plant, which works exclusively with newly developed chemicals; the second section makes Geon resins, which includes Geon polyvinyl chloride; Good-rite plasticizers are made in the third section of the plant; and general chemicals are produced in the fourth section. In the fall of 1950, a sales service laboratory was completed at the plant and this laboratory does all the development work for the company's chemical sales department.

Hooker-Detrex Corporation

A by-product of the metallic sodium process, chlorine gas, is compressed and piped from National Distillers to the Hooker-Detrex Corporation, where it is used with acetylene piped from Electro-Met in the manufacture of chlorinated solvents. These solvents find wide application in the metal degreasing and dry cleaning fluids. Hooker Electrochemical Company and Detrex Corporation joined forces to construct and operate the Hooker-Detrex plant. The entire output of trichlorethylene from the plant is distributed to industry through a network of Detrex Corporation field warehouses.

Harshaw Chemical Company

The Harshaw Chemical Company, one of The Chemical Shore's old-line companies, produces a diversified line of chemicals. Its major products are fluorides, hydrofluoric acid, opacifiers, paint dryers, pigments, and electroplating chemicals and anodes.

McGean Chemical Company

Cleveland's prominence in the plating field is further advanced by the McGean Chemical Company. This firm produces a widely diversified line of electroplating chemicals plus a large supply of chemicals for the ceramic and paint industries.

Other Progressive Chemical Companies

The Harris-Seybold Company manufactures lithographic chemicals. The Ohio Rubber Company, with its large plant in Willoughby, is one of the area's leading producers of rubber goods. The Ohio Chemical and Surgical Equipment Company, a division of Air Reduction, makes anesthetic and therapeutic gases. Industrial gases of many types are produced by Air Reduction and the Burdett Oxygen Company. Both of these companies make oxygen and acetylene for the large metal working market in Cleveland. The Barium Chemicals Company produces high-purity barium and strontium com-

pounds. The Cleveland division of the Archer-Daniels-Midland Company is the world's largest manufacturer of core oil. This plant supplies 50 per cent of America's and Canada's core oil requirements. Core oil is the varnish-like liquid used by foundries to bind cores together. The plant also makes liquid partings, which keep sand cores from adhering to the molds

What's Ahead for The Chemical Shore

At The Illuminating Company, it is firmly believed that chemical development in the Cleveland-Northeast Ohio area is still in its inceptive stages.

The future for the electrochemical industry in this area is bright. The resources are here. The transportation, the markets, the industrial potential are here. And available land is here—good land—for future-minded chemical companies. Approximately $40 million has already been committed for chemical expansion here during the next two years. That means those expanding companies will need much more electric power; it will be available to meet their increased demand.

Also we are glad to provide the location engineering services of our Development Department to *any* industrial firm interested in our area as a possible site for a new plant or for expansion of an existing plant. We provide these services free and without obligation on the part of the user.

What we strive for are industries that will strengthen the economy of our area, upbuild levels of business and industry, increase employment and job opportunities, and enhance payrolls and profits.

We believe that community growth is dependent, above all else, on growth of local industry. I hope this article has outlined some of the advantages which we feel make the Cleveland-Northeast Ohio area "the best location in the nation" for the chemical industry.

Because of this area's advantages, we believe the outlook for the successful production of the following products is especially favorable: synthetic resins, pharmaceuticals, solvents, rayon, soap and detergents, metallurgical products, paints and pigments, fluorinated compounds, antiknock compounds, and special agricultural chemicals.

Small chemical companies are encouraged to locate here as well as larger ones. Small industry is every bit as important to this area's development as big industry. The well-balanced area must have both.

The Cleveland Electric Illuminating Company welcomes the growth in our area of chemical companies—large and small. It helps our area grow, helps support the best possible standard of living, and, more important, the chemical industry is a bulwark of our national economy. Its products are vital to the national security and to international peace.

There is no foreseeable limit to the development of the chemical industry in the Cleveland-Northeast Ohio area.

ANOTHER TOP VALUE FOR THE CHLOR-ALKALI INDUSTRY...

NATIONAL CARBON'S *NEW* SERIES 310A "KARBATE" BRAND HEAT EXCHANGER

• Featuring lower cost per unit area of heat transfer surface . . . a new, improved version of National Carbon's shell-and-tube-type heat exchanger with corrosion-resistant "Karbate" brand tube-bundle and covers.

Get complete details of this **long-life, low-maintenance** unit in Catalog Section S-6740.

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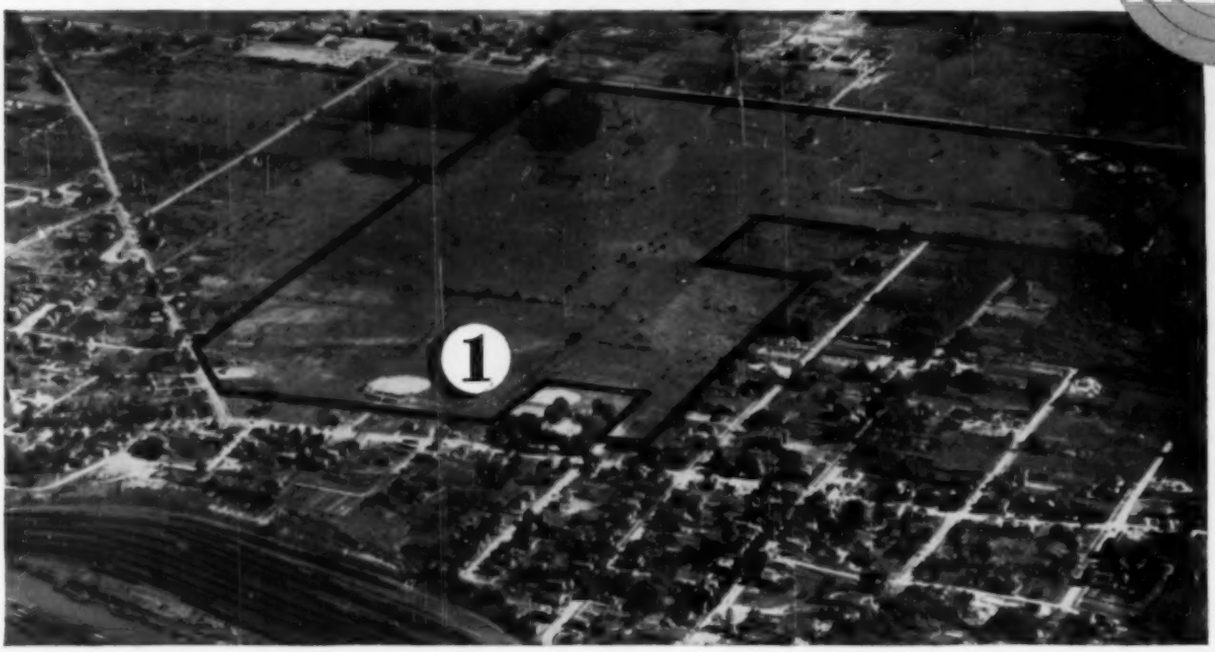
BEST LOCATION IN THE NATION

Headline Industrial News from the Cleveland-Northeast Ohio Area



① *Ashtabula City Site, 175 acres, 1½ miles north of main city district near Ashtabula harbor.*

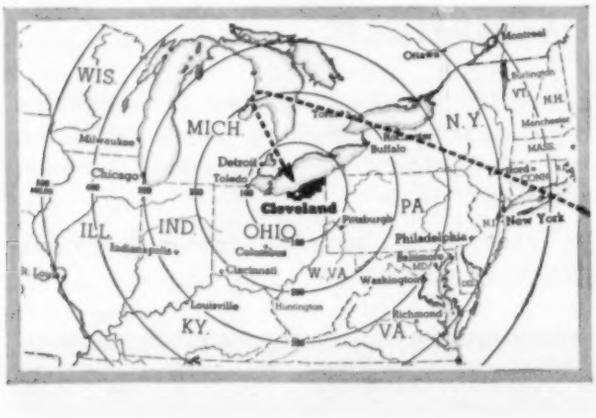
2 LARGE NEW PLANT SITES NOW AVAILABLE ON LAKE ERIE'S "CHEMICAL SHORE"

Shown on this page are two outstanding new plant sites, both located in small-city or semi-rural areas within an hour and a half drive of Cleveland.

Ideally located for chemical production as well as many types of general manufacturing, with numerous basic chemicals at hand, these sites offer easy access to mainline rail and highway facilities, soil conditions favorable to heavy structures, nearby lake ports.

Utilities—Dependable electric power supply available from Cleveland Electric Illuminating Company 1,144,000-kilowatt interconnected system. Natural gas available in area. Unlimited fresh water from Lake Erie.

Nearby Communities—Ashtabula and Lake Counties have a combined population of 170,000. Both sites easily accessible by automobile or bus.



Low Taxes—Property taxes per $100 valuation are low in the two townships: Ashtabula $1.28; Perry $2.33. City of Ashtabula: $2.61.

A Rare Opportunity—Act Today

For complete information about either of these new sites and the opportunities for your company here, phone, wire or write Development Department, Richard L. DeChant, Manager. All inquiries held in strict confidence.

② *Perry Township Site, 368 acres, Lake Erie frontage 2500 feet, 20 miles southwest of Ashtabula, 8 miles northwest of Painesville.*

THE BEST LOCATION IN THE NATION — 81,000,000 customers within 500 miles... 3,500 manufacturer-suppliers right at hand

THE CLEVELAND ELECTRIC ILLUMINATING COMPANY

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The Development of Rare Metals[1]

J. W. Marden[2]

Introduction

On an occasion of this kind one is at a loss for words to express to the Society, and to friends, his thanks for the great honor that they have awarded him. One feels as though he had been given more than he deserves, since the accomplishments of research are in modern days rarely the accomplishments of one alone, but rather those of many; some have laid the foundation for the work and others have carried or supplied the materials and read the measuring instruments. I not only owe you, tonight, a debt of gratitude for this great honor but I owe much to the Society, and in particular to those who have gone many years before us, who have, by their counsel and advice, guided my course and helped me to make a small measure of success.

In return, it is a pleasure to hand back to the Society the $1,000 which accompanies the Acheson Award. This money may be used by the Board either for augmenting the scholarship or award funds of the Society, or it may be used by the Board in any way considered to be to the best interests of the Society.

The Less Common Metals

The Electrochemical Society has, in its half century of existence, always fostered and encouraged work on the less common elements. Of course, such work is only one portion of the field covered by our Society but since some of these rare metals have now become of extreme importance, a brief discussion of their development with some indication of how the Society has aided may be of general interest.

At the beginning of the century, elements like uranium, thorium, vanadium, zirconium, or titanium were, to many chemists, only names in the periodic table. There seems to be no generic name for these metals. Perhaps they might be called "rare refractory metals" if the term "rare refractory" is defined to mean difficult to produce in pure metallic form freed of oxides, nitrides, or carbides.

Metals like gold are rare to some of us but they are precious metals. No matter how difficult gold is to obtain, it may be easily freed from oxygen impurities by simply heating. It is a noble metal. Metals like iron are readily obtained by reducing the oxides with carbon or hydrogen.

The group of metals under discussion cannot be electroplated from aqueous solution, nor can their compounds be reduced with hydrogen or carbon. They retain their last traces of oxygen and nitrogen impurities with great tenacity and these must be removed if the metals are to be ductile and pliable at room temperature.

These metals have been known as impure powders for over one hundred years but it is only within recent times that methods have been refined sufficiently so that good fabricated sheet and wire may be produced.

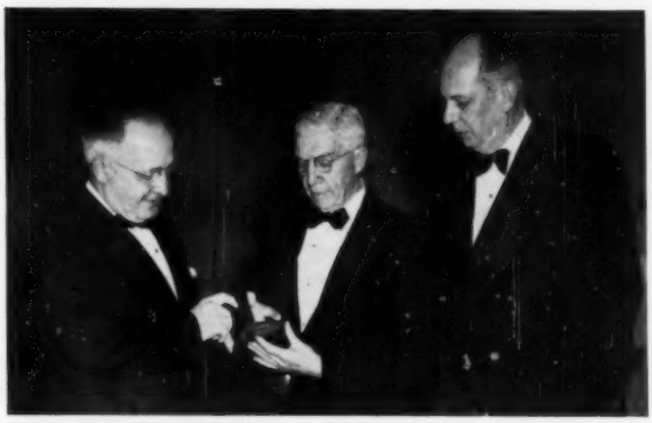
[1] Acheson Medal Address delivered at the Montreal Meeting, October 28, 1952.

[2] Consultant, Westinghouse Electric Corporation, Bloomfield, New Jersey.

Early experimenters used the same compounds and the same reducing methods that are used today. Broadly, four such methods have been employed with some degree of success:

1. The deposition of metals from volatile compounds was used to a limited extent by the carbon and tungsten lamp filament industry. The small quantity produced and equipment difficulties have prevented extensive commercial developments.

2. The reduction of oxides with aluminum or calcium is similar to the well-known thermite process. Unfortunately, in most cases, the heats developed during the reductions are insufficient to melt the metals or slags covering the charge.



Dr. John W. Marden receives the Acheson Medal from President J. C. Warner at the Montreal Meeting while Dr. C. M. Slack looks on. Dr. Slack introduced Dr. Marden at the banquet, outlining some of his many achievements; his talk appears immediately after this article.

3. Early experimenters attempting the reduction of chlorides with sodium, potassium, or magnesium experienced difficulty because of the extreme chemical activity of the halides.

4. Electrolysis of fused baths has always offered possibilities but in general only powders have been produced.

With the last three methods even if reductions could be made complete, the metals in fine powder form were, in the early days at least, partially reoxidized in subsequent handling.

During the first few years of the present century experimenters began to work with tightly sealed containers, but it was not until good vacuum pumps were in the hands of the chemist that a purer product could be made. A good vacuum, however, was not enough since some of these metals needed to be melted and cast prior to fabrication. At about the time of World War I high-frequency induction furnaces were developed and these were a great help in making pure metals.

It was possible, however, at the time of World War I, to

press powder, reduced in sealed containers, into bars or rods and pass current through them to metalize. It might be stated in passing that some of the work on rare metals was stimulated and fostered by the U. S. Government during World War I when a rumor came to this country that the Big Bertha, which bombarded Paris from great distances, was lined with either zirconium or zirconium steel. As it turned out, the rumor was false but much work was done to investigate the properties of such metals as zirconium and titanium. Work continued in the U. S. Bureau of Mines has resulted in methods now used for their commercial manufacture.

It is also interesting to those working on this subject to know that wires of sorts of zirconium, titanium, thorium, and uranium were made, sealed into lamp bulbs, and operated for tests as lamp filaments in the early 1920's. These filamentary wires were made by a method suggested by Von Bolton. Powders produced by reduction of oxides with calcium in sealed iron "bombs" were tightly packed into copper tubes and rolled down to small size. The thread of rare metal powder sheathed in the copper was fastened to lead in wires, mounted in glass bulbs, and attached to vacuum pumps. With this arrangement dilute acid could be drawn into the bulb to dissolve the copper and the filament could be washed with water. After drying, current was passed through the wire and the filaments were operated. At that time, interest centered in making lamp filaments, and since these metals did not appear to be satisfactory for such a purpose, a description of this was never published.

The metal produced in the early 1920's by passing current through pressed powder bars was not of sufficient quality to be entirely satisfactory. Zirconium and titanium so made could be hot-rolled or forged but were brittle at room temperature. Small amounts of thorium and uranium that could be fabricated into fine wire and sheet were, however, made at the time. There were, of course, no commercial applications and hence no reason to stimulate further improvement on methods of production.

In the early 1920's uranium and vanadium salts were drugs on the market. Howard Barker and Dr. Victor Hess, then employed by the U. S. Radium Company, strove vainly to find some outlet where they could sell these salts. They were having difficulty with the Department of Sewers in Orange, New Jersey, because they were contaminating the sewers and were even having trouble throwing the uranium away. This is certainly in sharp contrast to the demand for uranium today.

It should be pointed out that early experimenters and those of today are still having difficulties in finding suitable refractories in which to melt these metals and this problem is one of vital interest to some of our members.

In the latter 1920's, the scientists of the Philips Lamp Company in Holland greatly improved the vapor deposition method for producing very pure, ductile zirconium under good oxygen-, nitrogen-, and carbon-free conditions. This method is now employed to manufacture a very fine grade of zirconium used, in part at least, for medical purposes.

Within the last several years experimenters in the U. S. Bureau of Mines have developed their excellent processes for producing titanium. They reduce the chloride with magnesium, carefully excluding gaseous and other impurities. It is said that attempts are now being made to produce about 30 tons a day of this metal, which a very few years ago was only a laboratory curiosity. This is practically all absorbed for military purposes. Titanium is a particularly interesting metal since, volume for volume, it weighs only a little over half as much as iron or steel, and when alloyed can be given good room temperature hardness and strength. Some of you may have had the problem of studying the corrosion resistance of titanium.

Quantity production of uranium came during World War II and relatively large amounts of uranium are now manufactured for military purposes. When uranium and thorium were first produced in our laboratories it was assumed, since uranium was below tungsten in the sixth group of the periodic table, that it might have a higher melting point than tungsten, and that both uranium and thorium, since they had very high atomic weights, might be satisfactory metals to use as x-ray targets for deep therapy work. These assumptions have proved to be erroneous but the metals have found other and extremely important uses.

It has been stated that a knowledge of, and experience with, uranium greatly hastened work on atomic weapons, resulting in a shortening of World War II with a saving of many American lives.

The other less common metals are developing more slowly, but in like manner, and no doubt the day will soon come when some of them will be classed as useful household articles. There will always be much to be done. Chromium as electroplate is used everywhere but we still have the problem of making pure, ductile chromium metal in useful wire and sheet form, just as we have of many of the other less common metals. Judging from the literature, methods for producing rare metals by electrolysis of fused baths have not been fully developed and this problem belongs to members of this Society.

Contribution of the Society

Rare metals are being developed with increasing rapidity and as new and better equipment, such as vacuum pumps, furnaces, and handling techniques, become available, larger quantities of purer metals will be produced. One can scarcely prophesy the uses to which they will be put. If the past is an indication of the future, there should be many new and unexpected applications. The Society has done much to bring about these changes. It has offered a place in the JOURNAL for publication of new processes and discoveries and it has opened its doors to symposia and discussions on the subject of the less common elements. It has afforded a place where those employed in industry, the student, and the teacher may see and hear the leaders in their respective fields and from these contacts obtain the inspiration to continue.

According to Martin F. Quaely, the Society has published approximately 330 papers relating to the rare metals. To mention only a few, there have been 26 contributions on zirconium, 23 on titanium, 21 on chromium, and eight on uranium. This small number of papers on uranium has, of course, been due to the restrictions of security regulations.

Many owe much to the examples and words of wisdom of some of the great leaders of our Society. The speaker has been particularly influenced by the work of such men as W. D. Bancroft, one of our founders; W. Lash Miller, a great Canadian; Herman Schlundt, who did much to foster work on less common elements; H. S. Miner and C. James, of rare earth fame; Louis Kahlenberg and Colin Fink, to mention only a few. From my point of view, these men long ago reached the pinnacle of success.

Since some of you have been students of Kahlenberg, and since the story illustrates how the older members of the Society may be of real help to the younger ones, it should be of interest to recount a personal contact with this great leader.

It happened during an extended plant inspection trip at an Annual Meeting, approximately 35 years ago. Perhaps by previous arrangements of others, a young college teacher, who was trying to do some independent research, was introduced to Dr. Kahlenberg. The young man was thrilled and intrigued by the great teacher's attention and he was content for the most part to listen during the whole time of the trip. Many things were discussed in this long lecture not included in college courses of chemistry and physics. It can now be reported that the same things are the matter with the young research workers of today that were wrong with us 35 or 40 years ago. Of course, the old timers would frown upon the present day regimentation and the establishment of fixed hours of work. During the discourse, one gathered that young men were not as careful in their thinking as those who went before. When it was suggested that this might be a matter of viewpoint, it was soon found from the answers that such an argument was considered immature and immaterial. It might be said, however, it became very clear that there were rewards to research which are not necessarily monetary.

In conclusion, let me state that the young men of today have far better working conditions, better equipment, and better financial support, than those who preceded them. A research engineer is like a skilled mason working side by side with other masons. He lays his stone upon a scientific foundation built by others who preceded him, and he expects those who follow to lay their stones upon the ones he has so carefully placed on the wall. There are many more masons now than there were when the Society was organized. Before the days of scientific societies, technical skill was handed down by word of mouth from father to son. Today, we hand it down through our publications. There are still, however, many technical details which are only obtained by personal contact. It is hoped that the older and more mature members of our Society will always continue to encourage and help those who are to follow in their footsteps.

An Introduction with Comments on the Medalist's Achievements

C. M. Slack[1]

May I express my appreciation for the honor of participating in the presentation of the Acheson Medal to Dr. Marden. I would also like to commend this Society on the indomitable courage which it has shown in asking a physicist to sing the praises of a chemist. Somehow, it makes the prospects for international peace seem brighter.

At my first meeting with Dr. Marden back in 1927, he told me he was looking for a chemist. Being a physicist, I could offer him little in the way of advice, but I had thought that chemists were a pretty plentiful lot. It soon became apparent that Dr. Marden was not looking for an ordinary chemist; the word "electrochemist" had little meaning to me at that time. He wanted one who understood chemical reactions at high temperatures in a vacuum, and one who understood chemistry in the presence of electrical discharges. This was my first real impact with the degree of specialization required by industry for a scientist to fit into the complex team work needed to attack even a small segment of an industrial endeavor. It impressed me greatly. Dr. Marden realized fully the trend which industrial research was taking and had a clear view of what was required in the way of men and materials to accomplish it. Incidentally, he found such a man, who worked with him for many years, and who is now a vice-president in charge of development work for a large company.

Dr. Marden was trained in both chemistry and metallurgy, and I think he was the most versatile individual with whom I have ever been associated. He willingly tackled problems as they presented themselves to the Lamp Division, no matter into what branch of science they would normally fall; he concentrated on them with a singleness of purpose and a vigor which usually brought results in a minimum of time.

Dr. Marden has many outside interests. Perhaps, his chief one is farming in the country gentleman style. He is a collector of guns and an expert in their use. It is reported that his farm is freer of rabbits and groundhogs than any other in Morris County.

[1] Westinghouse Electric Corporation, Atomic Power Division, Pittsburgh, Pennsylvania.

Dr. Marden was born in Saginaw, Michigan, on May 11, 1887. He obtained his B.S. degree from Illinois Wesleyan University in 1909; he was a fellow at the University of Illinois in 1909 and 1910, received his M.S. degree from the New York University in 1911, and his D.Sc. in 1912. From then until he came to Westinghouse, he held such positions as soil analytical chemist at the University of Minnesota, assistant professor of chemistry at the University of Missouri, and metallurgist at the U. S. Bureau of Mines. He became assistant Director of Research of the Westinghouse Lamp Division in 1925, and held this position until 1947, when he was appointed Manager of the Molybdenum Development Department. Although retired in June of this year, he is still a consultant for the company in regard to metals and electrochemistry.

Dr. Marden's major researches have been in the field of extractive metallurgy of the rare metals and their application to lamps, electronic devices, and nuclear reactors.

At the outbreak of World War I, he volunteered his services to the Bureau of Mines and was assigned the preparation of zirconium metal. This formally started a long career in rare metal technology lasting more than thirty years. While at the Bureau of Mines, he was co-author of several very important monographs on rare metals.

His work includes many papers and patents related to methods of preparation, properties, and industrial applications of the rare metals. Early investigations on the preparation of thorium, uranium, vanadium, chromium, and zirconium in the late twenties secure him a place among the few remaining pioneers in this field. The commercialization of thorium of high purity by Marden and Rentschler represented an outstanding accomplishment. He demonstrated the possibility of producing ductile vanadium by calcium reduction of the oxide in the twenties. This process with some improvements has become standard procedure for the production of this metal.

It would obviously be impossible to recall even briefly in any significant detail such a ramified career, so I have decided

to select one phase of his work which perhaps has more glamour to it than others, and which I believe would be understood as to its import by everyone here.

Dr. Marden's early work on the production of uranium by calcium reduction of the oxide and magnesium reduction of the fluoride and his extensive knowledge of rare metal chemistry stimulated important new developments in uranium technology by associates in the Westinghouse Research Laboratories at Bloomfield.

He, together with Dr. Rentschler, had refined uranium metal in the very early days in the vain hope that its melting point might be high enough for use as lamp filaments, and so serve as a substitute for tungsten. For the first time, uranium was produced in a relatively pure form. As a consequence of this work the Lamp Division went into the production of uranium in the early twenties, supplying laboratories all over the world with experimental quantities of this interesting but relatively useless material. This work continued, and in the early thirties, under Dr. Marden's supervision a method was perfected for the production of uranium by the electrolysis of the fused salt.

In 1940, Dr. Marden and coworkers undertook the commercialization of the electrolytic process for the production of uranium metal under the Manhattan Project at Westinghouse. This development supplied most of the uranium metal for the first atomic pile at the University of Chicago.

Much of the success of this large-scale development may be attributed to the resourcefulness of Dr. Marden. The story goes that Bloomfield smelled to high heaven that summer because Dr. Marden had cornered the market on garbage cans for conversion into electrolytic tanks. Also, many a dirty shirt was being worn after he bought up all the wash tubs available. These he set out on the roof of the plant in order to carry on the production of potassium uranium fluoride by the photochemical action of sunlight. Unfortunately, it was rainy that spring and summer, and all hands had to be ready on a moment's notice to rush to the roof to cover the precious chemicals. Eventually, special arrangements were made for advanced weather information.

This work on uranium is classified information at the present time in an extensive report. Its import is best evaluated by reference to a letter to the Westinghouse Electric Corp. from Dr. Arthur E. Compton, Project Director, quoted below:

October 6, 1945

Mr. A. Frankel,
Westinghouse Electric Corporation,
Bloomfield, New Jersey.

Dear Mr. Frankel:[2]

Now that the war has been successfully completed, the "Atomic Power Project" is undergoing complete reorganization in an attempt to place its activities on a long time basis. As a result of this change, the Metallurgical Project Office, through which I have discharged my responsibilities, is being closed out.

Before relinquishing my active responsibilities, I wish to express to you my deep appreciation of the help which Westinghouse Electric Corporation, in making available the services of J. W. Marden, rendered. While at a later date other methods supplanted those developed at Westinghouse, our initial supply of metal was dependent upon your efforts, and the initial success of our work was determined by the Westinghouse production.

I am writing Dr. Marden directly, but I would appreciate your expressing my thanks and those of the project to all the members of your staff whose cooperation made Dr. Marden's work effective.

Sincerely,
Arthur E. Compton
Project Director

[2] Mr. Frankel was in charge of contract arrangements between the Project and Westinghouse.

As Manager of Molybdenum Development since 1947, Dr. Marden has been engaged in diverse projects under government sponsorship. Outstanding developments include the fabrication of very large pieces of molybdenum and extensive studies on the effects of heat treating and fabrication on the physical properties of the metal.

Over a long period of years, Dr. Marden has made many important contributions in the fields of gaseous discharge devices, lamps, and electronic tubes. Specific examples are his work on the Cesium Amplifier Tube, the G-5 Ultraviolet and Germicidal Lamp (this was one of the earlier types of sun lamps), and the sodium, cadmium, zinc, tellurium, and arsenic lamps.

He did extensive work on the high pressure mercury vapor lamp, which included initial experimentation in the company on mercury pressures up to 30 atmospheres.

Other investigations included those on the low pressure mercury vapor fluorescent lamp, the effects of trace impurities in phosphors on light output during the early stages of fluorescent lamp technology.

During his long career, Dr. Marden has had 71 patents issued, covering a wide field from basic metallurgy to lamps and x-ray tubes.

I do not feel qualified to relate his experiences with the Society. Dr. Marden, however, has told me how much the Society has meant to him, and others have described how much he has meant to the Society, particularly in its struggle for existence during the early thirties.

This honor being conferred upon Dr. Marden by The Electrochemical Society is one of which any man would be proud, and it comes to Dr. Marden after a long and illustrious career as a scientist. In turn, The Electrochemical Society has every reason to feel proud that they have such a worthy member of their organization as a recipient of this honor. The many friends that Dr. Marden has both inside and outside of scientific circles are equally proud of his accomplishments and of this honor which he is receiving here tonight.

I am sure that I express the feeling of the members of the Society and of his colleagues in Westinghouse and elsewhere in wishing him many more years of a fruitful and interesting life, with more leisure to concentrate upon those accumulated personal wishes than are allowed in the hectic life of industry

Current Affairs

Early Plans for the New York Meeting—April 1953

Interest in the forthcoming spring meeting of the Society in New York City has been greatly stimulated by the development of plans for a program which offers a number of exceptional features, in addition to a fine technical schedule. A visit to New York is in itself an incentive, and a few of its attractions are touched on in the columns below. The meeting will take place at the Hotel Statler, New York, from April 12 through April 16, 1953. Completed and tentative plans, as of this writing, are outlined below.

New York Convention and Visitors Bureau

The United Nations Building shown from the side facing the East River

Visiting New York for the Spring Meeting

New York, with its myriad attractions, offers much to visitors and residents alike. There is something to see and do anytime, any day, uptown, midtown, or downtown.

If you arrive in the city at Grand Central Terminal, you will see the largest and most costly terminal in the world. Across from it is the Chrysler Building which towers 1045 feet into the air. This is the midtown area in which are located the Public Library, Metropolitan Opera House, Madison Square Garden, Rockefeller Center, St. Patrick's Cathedral, the United Nations, theaters, the smart shops, and many other points of interest.

Visitors can take a subway ride and travel 32 miles for a dime. Located downtown are the Bowery, Bowling Green, and Brooklyn Bridge, and a visit may be paid to the Stock Exchange. Also in this section are Chinatown, the Custom House, Ellis Island, Fraunces Tavern, Holland Tunnel, Manhattan Bridge, Police Headquarters, Seamen's Church Institute of New York, Old John Street Church and St. Paul's Chapel, and the Statue of Liberty.

Upper New York has further points of interest. Places to visit include the American Numismatic Society, Bronx Park and Zoological Gardens, Cathedral of St. John the Divine, Central Park, Columbia University, George Washington Bridge, Grant's Tomb, Jumel Mansion, Medical Center, New York University, Poe Cottage, Riverside Church, Van Cortlandt Mansion, Hayden Planetarium, Metropolitan Museum of Art, American Museum of Natural History, Polo Grounds, and Yankee Stadium.

The Technical Program

Arrangements for an extensive technical program are underway, with simultaneous sessions to be held Monday through Thursday. These sessions are being scheduled for the Sky Top, the Penn Top, and the Keystone Rooms at the Hotel, all of which are of ample size.

A special feature of the program will be a Symposium on the Application of Electrochemistry to Biology and Medicine, which is being sponsored by the Theoretical Electrochemistry Division; it is expected to run for three days, or six sessions. In connection with this, there will be a Symposium Dinner on Monday evening with a talk relating to the symposium.

The Theoretical Division plans to present additional papers, and may have a joint session with the Electronics Division on semiconductors.

The Electronics Division has a full program including a symposium on Luminescence (probably two days), one on Screen Application (one day), and another based on Semiconductors (at least one and possibly two days). "Extended Abstracts" booklets of these papers will be on sale at the meeting.

Another feature of the program will be the Richards Memorial Lecture on "Transistor Physics." This is described in detail below, and will be of special interest in connection with the technical program on semiconductors.

The Electrothermic Division will present a series of papers by the authors of the monograph entitled "High Temperature Materials, Methods and Measurements." A number of the contributors to this monograph have completed their assignments, and they will be asked to review their contributions at the meeting. In addition, there will be general papers concerned with electrothermics.

The Electric Insulation Division is planning four sessions treating on

Electrophysics, Applied Dielectrics, Capacitors, and Electric Insulation; also, a luncheon honoring Peter Debye is being arranged by this Division.

Luncheons, Dinners and Committee Meetings

Meetings will be held by the Ways and Means Committee and by the Board of Directors on Sunday, April 12. Other committee meetings to be held will be announced later.

The Society Luncheon will be held on Monday noon, and will be followed by a nontechnical talk. On Monday evening there will be a reception and dinner in connection with the Symposium on the Application of Electrochemistry to Biology and Medicine.

The Reception and Banquet of the Society will be held on Tuesday evening, April 14, and this will be the occasion of the Presidential Address by J. C. Warner. Dancing will follow the formalities.

Division Luncheons are planned by the Electronics, Electric Insulation, Theoretical, and possibly by the Electrothermic Divisions. The luncheon of the Electric Insulation Division will be a special affair in honor of Professor Peter Debye, who will speak on the subject, "The Electrical Interpretation of Molecular Forces." Professor Debye is the Nobel Laureate whose name is associated with dipole molecules, X-ray patterns, paramagnetic cryogenics, ionic conductivity, and, recently, light scattering of polymer sols. Time and place for these luncheons will be announced in the Program Booklet.

Richards Memorial Lecture

The Richards Memorial Lecture will be given on the afternoon of Wednesday, April 15, by Dr. William Shockley of the Bell Telephone Laboratories. In his lecture, titled "Transistor Physics," Dr. Shockley will discuss the fundamental principles on which this new and revolutionary device operates. He will describe the more recent developments and improvements, indicating some of the applications being considered. The point-contact transistor, announced in 1948, was invented by J. Bardeen and W. H. Brattain while working under Dr. Shockley's supervision. Dr. Shockley holds several transistor patents, in particular that of the "junction transistor."

Born in London in 1910 of American parents, he attended schools in California and, in 1932, received a B.Sc. degree with physics major from the California Institute of Technology. He was a teaching fellow at the Massachusetts Institute of Technology from 1932 to 1936, when he received the Ph.D. degree. His thesis was on wave functions of electrons in crystals.

Upon leaving M.I.T., Dr. Shockley joined the staff of Bell Telephone Laboratories, and for about one year worked upon electronic devices before returning to solid state physics, particularly theories of the order-disorder transformation of alloys. From 1940–42, he worked on radar design and developed several circuits that found general use in radars manufactured by the Western Electric Company. During

L. I. Gilbertson
Chairman, Registration Committee

the remainder of the war years, he was engaged on Operations Research with the Navy and Air Force, following which he returned to Bell Laboratories and continued his activities in solid state physics in part in a supervisory capacity.

Dr. Shockley is a member of Tau Beta Pi, Sigma Xi, a Fellow of the American Physical Society, a Senior Member of the Institute of Radio Engineers, and a member of the National Academy of Sciences.

Plant Trips

After careful consideration of the transportation problems in taking registrants to and from plants in the New York City area, and because of restrictions on visitors at many of the plants engaged in government work, the Plant Trip Committee decided not to offer any organized plant trips at this meeting. However, if individuals or small groups desire to visit a specific plant in the Metropolitan New York area, G. A. Lux, Chairman of the Plant Trip Committee, should be consulted at the registration desk and every effort will be made to make arrangements for such visits.

It should be remembered that there are but few plants on Manhattan Island of interest to the members of the Divisions attending this meeting. Therefore, a considerable portion of the day would be required to reach, and return from, points in the outlying area be-

G. A. Lux
Chairman, Plant Trips Committee

cause of extreme traffic congestion during morning and late afternoon rush hours. Thus, a plant trip would conflict with attendance at technical sessions and might interfere with evening plans.

Ladies' Program

A Ladies' Headquarters Room has been set aside in the hotel for the duration of the convention. This will be on the mezzanine floor in the vicinity

F. A. Lowenheim
Chairman, Finance Committee

of the registration area, and will give the ladies a chance to gather, and discuss their plans. An Information Desk will be set up in the registration area where advice can be obtained about entertainment, restaurants, theaters, night clubs, and other activities in New York City. It is planned to have tickets available for TV and radio broadcasting studios on Sunday evening and perhaps on other evenings during the convention.

The first scheduled event for the ladies will be the Society Luncheon on Mon-

day in the Keystone Room to which all members and guests are invited. Following the luncheon there will be a brief business meeting, followed by a talk of general interest by a popular speaker. Immediately afterwards there will be a Ladies-Get-Together in the Keystone Foyer.

Tuesday has a full schedule for the ladies. During the morning there will be a bus tour of up-town New York; at noon Tuesday, a luncheon in the Washington Square Room of the Fifth Avenue Hotel; and during the afternoon a bus tour of down-town New York, all of which will be complimentary. In the evening there will be the Reception and Banquet of the Society, followed by dancing.

During the remainder of the Convention the Ladies' Committee will conduct escorted trips for small groups. Some of the more popular trips will be planned in detail and tickets will be required in advance. These will probably include the United Nations, Radio City, the Metropolitan Museum, Hayden Planetarium, the Empire State Building, and a luncheon and fashion show. Full use should be made of the Ladies' Headquarters Room in arranging these activities.

Heading the Ladies' Committee are Mrs. C. G. Fink, *Honorary Chairman*, and Mrs. A. C. Loonam, *Chairman*. Other members include Mrs. H. Bandes, Mrs. H. R. Copson, Mrs. L. I. Gilbertson, Mrs. C. J. Lang, Mrs. H. B. Linford, Mrs. F. A. Lowenheim, Mrs. F. P. Peters, and Mrs. D. Wood.

Local Committees

The local Committee is composed of Colin G. Fink, *Honorary Chairman*; H. R Copson, *General Chairman*; K. G. Compton, *Chairman of Advisory Committee*; L. I. Gilbertson, *Registration*; H. Bandes, *Entertainment*; F. A. Lowenheim, *Finance*; G. A. Lux, *Plant Trips*; F. P. Peters, *Publicity*, A. C. Loonam, *Arrangements*; and Mrs. A. C. Loonam, *Ladies' Program*.

Corrosion Prevention Seminar at Stevens

A series of ten lectures on corrosion prevention will be given at Stevens Institute of Technology in Hoboken, New Jersey, on Thursday evenings starting February 12, 1953. The speakers are: T. P. May, International Nickel Company; F. L. LaQue, International Nickel Company; C. L. Bulow, Bridgeport Brass Company; H. W. Fritts, Aluminum Company of America, E. A. Tice, International Nickel Company; L. P. Sudrabin, Electro Rust-Proofing Corporation; A. Black, Shell Oil Company; A. G. Gray, *Steel* magazine; G. W. Oxley, Standard Oil Development Company; and K. Tator, Consultant.

This series of lectures is given in cooperation with the National Association of Corrosion Engineers and is available to the general public. Further information regarding admission may be obtained from the Admissions Office, Stevens Institute of Technology, Hoboken, New Jersey.

Pictorial Glimpses at the Montreal Meeting

Top row, left to right: Dr. J. W. Marden receives the Acheson Medal from President J. C. Warner with the approval of Dr. C. M. Slack, Dr. William Blum, and Dr. G. W. Vinal; familiar faces at the get-together in the Cartier Room before dinner Monday evening; President Warner, Mayor Camillien Houde, George Hogaboom, and Mrs. Blum flank General Chairman A. W. Whitaker, Jr., as he welcomes members and guests to the meeting at luncheon on Monday.

Center row, left to right: members of the Ladies' Entertainment Committee who helped make the Montreal Meeting such a success; George Hogaboom looks at Dr. Blum's Honorary Membership scroll with Dr. Blum and President Warner; General Chairman Whitaker, President Warner, and Dr. Martin at the cocktail party Monday preceding the dinner at which Dr. Martin was speaker.

Bottom row: informal shots at Monday and Tuesday dinners.

Highlights of Board of Directors' Meeting

(Held October 26, 1952, Mt. Royal Hotel, Montreal, Canada)

The financial structure of the Society was discussed. The budget for the year 1952 predicted a deficit of $1,130. As of the end of September, the principal items of income were holding up in such a manner as to indicate rather clearly that our total of $63,600 income would be met. However, items of expenditures, with respect to advertising agents' commission, were completely upset due to the resignation of Mr. Richard Rimbach as our advertising representative. The mode of operation with Mr. Rimbach was to pay him his commission for the preceding year during the month of January. This amounted to $730. However, since he resigned effective August 31, 1952, his commission will have to be paid on the 1952 advertising before the end of the year. In addition, it was necessary to give Mr. Jack Bain, our new advertising representative, a guaranteed minimum of $100 a week for expenses, beginning September 1. This combination of expenditures in connection with our advertising will most certainly result in a deficit of $2,000 in excess of that estimated.

The activities of our new advertising representative have been very encouraging. It is the opinion of the Secretary that advertising during the year 1953 will be sufficient to balance the budget and allow both the building up of our reserve funds and expansion of our JOURNAL. Since actual contracts are not expected until December, it is impossible at this time to give any concrete figures to support this belief. However, it is definitely expected that at the next Board meeting a completely altered financial picture may be presented.

Dr. William Blum was appointed to act as the official representative of The Electrochemical Society on his forthcoming tour through Australia.

Winners of the Prize Essay Contest were announced as follows: first prize winner, Gordon Gemmell, Massachusetts Institute of Technology, Cambridge, Mass.; second prize winner, Donald W. Hutchings, Oberlin, Ohio; honorable mention, Robert Auerbach, New York City. Mr. Heise reported that the Cleveland Section is planning to honor Donald Hutchings at a forthcoming sectional meeting. It was also agreed that these Prize Essay Contests should be continued.

The Secretary was granted permission to reprint 1000 copies of our "Aims and Activities" booklet.

The detailed report of the JOURNAL activities was presented by the Editor, and is summarized in part below.

Technical papers published in the Journal:

1948	*1949*	*1950*	*1951*	*1952*
63	68	65	79	85

Divisional contributions to Technical Section in 1952:

Division	*No. of papers received*	*% of total*	*Papers rejected*
Battery	16	8.69	0
Corrosion	32	17.39	5
Electric Insulation	8	4.34	0
Electrodeposition	26	14.13	1
Electronics	34	18.47	2
Electro-Organics	7	3.80	1
Electrothermics	4	2.17	0
Industrial Electrolytic	7	3.80	1
Theoretical Electrochemistry	40	21.73	8
Miscellaneous	10	5.43	3
Total	184	99.95	21

Comparative printing costs of 1951 and 1952 Journals

	1951		*1952*	
January	(60)	$1461.43	(68)	$1566.26
February	(60)	1408.07	(72)	1557.76
March	(68)	1641.80	(76)	1805.44
April	(60)	1431.50	(84)	2079.14
May	(56)	1291.58	(60)	1389.14
June	(68)	1544.24	(84)	2040.28
July	(64)	1488.09	(64)	1606.51
August	(56)	1328.25	(88)	2369.72
September	(56)	1331.96	(76)	2012.81
October	(56)	1361.92	(92)	2282.14
November	(68)	1540.83	(80)	—
December	(92)	2041.15	(132)*	—
	(764)	$17,870.82	(976)*	$18,709.20†

* Estimated
† 1952 budget is $24,000.

Dr. Harry Copson, General Chairman of the New York Meeting, reported the dates April 12–16 set for the 1953 Spring Meeting at the Statler Hotel. Registration is expected to be approximately the same as at former spring meetings. It was agreed that symposia chairmen and speakers at the Symposium on the Application of Electrochemistry to Biology and Medicine be charged member registration fees.

The report of the Membership Committee indicates that the Committee is very active in building up the membership of the organization.

The Sustaining Membership Committee reports that the following companies have enrolled since the last meeting held in Philadelphia: Auto-City Plating Company; Eaton Manufacturing Company; Ford Motor Corporation; General Motors Corporation; Merck and Company; National Research Corporation; Poor and Company; Wagner Brothers, Inc.; Yardney Electric Company.

The Ways and Means Committee requested that the Secretary circularize the membership, informing them that the preparation of a Ten-Year Index will be undertaken as soon as 400 prepayments of $10 each have been received, and that a publication date will be announced in the JOURNAL. After that date, the price will be $15. This recommendation was approved by the Board.

The Board also approved a further recommendation in which the Society was to invest $5,200 of the Roeber Research Fund, $2,000 of the earnings of the Acheson Fund, $2,800 of the earnings of the Weston Fund, $1,000 that will be returned by Dr. Marden from the Acheson Award, along with $3,000 of the Richards Memorial Fund, income from the last item to be kept separate from the remainder. The remainder is to be used for a consolidated fellowship at such time as the income is sufficient to insure fairly continuous operation of that fellowship. The investments were to be in two funds, one of the type of the Wellington Fund, and the other of the type of the Fundamental Investors.

The Ways and Means Committee further recommended that the Nominating Committee be appointed at the spring meeting and instructed to report by June 15. The Secretary is to furnish them with the list of names of all past Board members and chairmen of sections and committees for the last ten years. Sections and Divisions are also to be reminded of their privilege of suggesting to the Nominating Committee the names of eligible candidates. This recommendation was approved.

The Palladium Medal Committee was reappointed to serve without precedent. This committee is composed of J. C. Warner, R. M. Burns, Harry Copson, and H. H. Uhlig.

The next meeting of the Board of Directors was set for 10:00 A.M., January 30, 1953, at the Society's Office.

HENRY B. LINFORD, *Secretary*

NACE Conference in Chicago, March 16–20

The 1953 Annual Conference and Exhibition of the National Association of Corrosion Engineers will be held in March 16–20, at the Hotel Sherman, Chicago.

Included in the program will be a symposium on Protective Coatings in which five papers are scheduled; the Corrosion Principles Symposium with four papers; the Chemical Industry Symposium presenting eight papers; the Oil and Gas Industry Symposium with three papers; the Electrical and Communications Symposium with four papers; and others to be announced later. There will also be a round-table discussion on refinery corrosion problems.

Central Electrochemical Research Institute, India

The Central Electrochemical Research Institute at Karaikudi, South India, is one of the National Laboratories planned by the Council of Scientific and Industrial Research, India. The construction of the building for the Institute is nearing completion and it is expected to be in full operation in the early part of 1953. An article describing the Institute has appeared in the *Bulletin of the India Section of The Electrochemical Society*, Volume 1, pages 4–5, 1952.

T. L. R. C.

Spectrographers Symposium in May

The American Association of Spectrographers is planning a symposium on "Emission Spectroscopic Determination of Metals in Non-Metallic Samples." The symposium will be held in Chicago on May 1, 1953. Contributed papers in the fields of petroleum, geology, agriculture, pharmacy, biology, ceramics, etc., are welcome. Please address all inquiries to: J. P. Pagliassotti, Chairman, Symposium Committee, % Standard Oil Company (Indiana), Box 431, Whiting, Indiana.

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SECTION NEWS

Cleveland Section

The Cleveland Section was honored to have Society President Dr. J. C. Warner as its guest speaker at its December 9th meeting, held at the Cleveland Engineering Society Building.

Dr. Warner spoke on the "History of Theories of Electrochemistry." He told of the early contributions made by Faraday, Clausius, and Van't Hoff. He pointed out that the Arrhenius theory held sway, with various modifications until about 1923 when the Debye-Hückel theory was developed. Dr. Warner then discussed at length the basis and the significance of this theory and of some of the modifications of it, particularly those by Onsager.

The talk was received with keen interest by all.

J. M. MARGOLIS, *Secretary*

Detroit Section

Richard S. Atwood, Research Chemist at the Bersworth Chemical Company, Framingham, Massachusetts, was the guest speaker at the November 21 meeting of the Detroit Section, held at Wayne University. A filet mignon dinner and social hour preceded the technical meeting.

Mr. Atwood's subject was "Chelating Agents and Their Practical Applications in Cleaning, Electroplating, and Allied Industries." The speaker demonstrated the ability of chelating agents to form complexes with various metals, thereby reducing the metal ion concentrations to values where interference with desired reactions does not occur.

One specific example discussed by Mr. Atwood was the complexing of copper present in bright nickel baths. Studies of the effect of chelating agents on bond strength, and corrosion resistance of the electrodeposited coatings have not yet been completed.

The lively discussion period which followed Mr. Atwood's talk was a tribute to its stimulating qualities, and reflected the interest of the Detroit Section and its guests in subjects relating to technical progress in the field of electrodeposition.

G. V. KINGSLEY, *Secretary-Treasurer*

Niagara Falls Section

A joint meeting of the Niagara Falls Section with the National Association of Corrosion Engineers and the American Institute of Chemical Engineers took place at the Red Coach Inn, Niagara Falls, on November 12. This joint meeting was suggested by, and arrangements for the speaker were made by, NACE. The attendance was excellent, with 94 members and guests of the three societies present for dinner, and a total of 120 for the talk following.

The speaker, Thomas P. May, of the Corrosion Engineering Section of

THOMAS P. MAY

the International Nickel Company of New York, talked on the subject "Choosing a Metal." Dr. May has concentrated on marine corrosion since 1939. From 1939 to 1947 he was a member of the Research Staff of the Chemistry Division, Naval Research Laboratory, Washington, D. C., and was head of the Corrosion Section there from 1943 to 1947. He joined the International Nickel Company in 1947.

Dr. May described some of the fundamental principles that should be considered by an engineer in selecting metals for equipment or structures. His presentation included a discussion of electrode potentials and their relation to corrosion rates, both in the corrosion of base metals and of galvanic couples. He then discussed several forms of corrosion attack that are commonly encountered in process equipment.

M. JANES, *Secretary-Treasurer*

Midland Section

At its November 28 meeting, the Midland Section of the Society heard an address by R. F. Humphries, Chairman, Physical Research Department of Armour Research Foundation, Chicago; his topic was "Nuclear Tracers in Chemical Processes."

Dr. Humphries outlined the principles of the tracer work including the α, β, and γ particles, and also showed slides of the various instruments useful for measurement.

* * *

The executive committee of the Detroit Section, including H. H. Roth, Chairman, W. R. Perry, Vice-Chairman, and F. N. Alquist, recently named committees to serve for 1952-53. They include:

Program—W. R. Perry, R. D. Blue, and R. C. Kirk

Membership—P. F. George, M. P. Neipert, and R. E. Friedrich

Nominating—H. A. Robinson, H. E. Houser, and W. S. Loose

Publicity—R. S. Karpiuk and R. L. Thrune

W. R. PERRY, *Secretary-Treasurer*

New York Metropolitan Section

The New York Metropolitan Section held a meeting on December 10, at which Moses D. Heyman, Integrated Mica Corporation, Woodmere, New York, spoke on the subject "Integrated Mica."

Dr. Heyman is a pioneer in developing this new material and is a member of the Reconstituted Mica Committee under the auspices of the National Research Council.

He displayed a thorough grasp of a subject which turned out to be of considerable interest and fascination, and he illustrated his talk with many samples of mica sheets which had been fabricated from scrap. It is not generally realized that mica in the form of large sheets is an extremely strategic material and that the ability to closely duplicate properties of natural sheet mica by "integrating" the much cheaper and more available small flakes, which are normally considered practically a waste product, can go far to eliminate our reliance on foreign sources.

Presumably because of the nearness to the Christmas season, the audience was of relatively smaller size than usual, but there was no lack of interest and discussion.

F. A. LOWENHEIM, *Secretary*

India Section

The Fourth Technical Meeting of the Section for 1952 was held on November 29 at the Central Electrochemical Research Institute (C.E.C.R.I.), Karaikudi, with Dr. A. Joga Rao in the chair in the absence of the chairman and vice-chairman. Three speakers addressed the gathering on the subjects outlined below.

Dr. T. L. Rama Char of the Indian Institute of Science, Bangalore, delivered a lecture on "Some Aspects of the Electrodeposition of Cadmium." The speaker first stated the importance of cadmium plating and then gave an

account of the work carried out in his laboratory on the electrodeposition of cadmium and cadmium-zinc alloys from the sulfamate bath.

The bath was found to compare well with the cyanide bath in respect to current-density range and current efficiencies. The advantages of this bath over the cyanide bath were: simplicity of composition, stability, nonpoisonous nature, rate of control, and maintenance and production of bright plates without the use of addition agents. The cyanide bath gave finer-grained deposits and possessed better throwing power.

The electrochemistry of the cadmium sulfamate solutions was then touched upon with specific reference to the experimental results of the effect of the common variables on plating and the significance of polarization data. Measurements of the cathode potentials of cadmium and zinc indicated that it was possible to co-deposit the two metals from these solutions. Alloy deposits with a wide range of composition could be obtained by varying the operating conditions.

J. Balachandra, Department of Metallurgy, Indian Institute of Science, then gave a brief report of his work on the use of the fluoborate bath for cadmium plating. He stated that the performance of the fluoborate bath was quite comparable to that of the cyanide bath and that it offered interesting possibilities in the field of commercial plating.

V. Aravamuthan, Central Electrochemical Research Institute, Karaikudi, delivered a lecture on "The Industrial Applications of Electrolysis of Water." The lecturer pointed out the best methods for utilizing the products of electrolysis of water in industries that could be started at or near the electrolysis plants, and also mentioned the industries that could benefit from the products of electrolysis in spite of the distance from the plants. According to him, the production of synthetic ammonia, urea, nitric acid, ammonium nitrate, methane, ethylene, acetylene, benzene, toluene, and products that could be catalytically obtained from the above, as well as the products that could be obtained from these organic chemicals by reaction with nitric acid and/or by reaction with electrolytic hydrogen, would be commerically very successful. In these processes, besides air and water, only cheap carbon dioxide, by-product of fermentation industries, is employed.

Interesting discussions followed these lectures and the Secretary expressed the thanks of the Section to Dr. A. Joga Rao, and to the staff of the Central Electrochemical Research Institute for giving all facilities in arranging for this meeting, the second one outside Bangalore. With a vote of thanks to the speakers, the technical meeting came to a close. The program was rounded off with tea arranged by the Section for the members and guests, and a visit to the C.E.C.R.I., one of the National Laboratories of India.

* * *

The *Bulletin of the India Section of The Electrochemical Society* has completed one year. It was started in January 1952, and four numbers were issued during the year.

J. Balachandra, *Secretary*

HENRY F. KLEINFELDT

Henry F. Kleinfeldt, vice-president of Abbe Engineering Company, New York City, died at his home in Bloomfield, N. J., on June 6 last.

Mr. Kleinfeldt had been with the Abbe organization for more than 40 years and had been active in the development of many mixing, pulverizing, and blending operations which are standard practice in industry today. He was a longtime member of The Electrochemical Society, which he joined in 1915.

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PERSONALS

LAUREL E. PUTNAM of Ft. Belvoir, Virginia, is now employed as chief engineer at Superior Air Products Company, Newark, N. J.

MYRON T. CORY, formerly of Great Lakes Carbon Corporation, Niagara Falls, N. Y., has been named president of Graphite Specialties Corporation in Niagara Falls.

BERNARD C. CASE has left the Hanson-Van Winkle-Munning Company, Matawan, N. J., to accept a position with Sunbeam Corporation, Chicago, Ill.

WILLIAM F. O'CONNOR, associate professor of chemistry at Fordham University, New York City, has been named Chairman of the Department of Chemistry, Fordham University.

HARRY K. IHRIG, vice-president in charge of research, Allis-Chalmers Manufacturing Company, Milwaukee, has been elected to the Board of Directors of Nuclear Instrument & Chemical Corporation, Chicago. Dr. Ihrig is nationally known for his research in metallurgy and related fields.

KENNETH J. KELLY of Pratt & Whitney Aircraft Division, United Aircraft Corporation, Hartford, has been assigned to work, on loan, in the Materials Chemistry Division of the Oak Ridge National Laboratory, Oak Ridge, Tenn.

MAX E. BRETSCHGER, formerly vice-president of Buffalo Electro-Chemical Company Inc., Buffalo, N. Y., has been elected president of the company, filling the vacancy created by the death of the late Charles A. Buerk. GEORGE G. CREWSON, director of engineering, Buffalo Electro-Chemical Company, has been elected to the Board of Directors.

T. L. RAMA CHAR of the Indian Institute of Science, Bangalore, India, has been awarded the Fellowship of the Royal Institute of Chemistry in London.

P. A. CHENGAPPA, D.C.M. Chemical Works, Delhi, India, has left for Germany to work in a caustic soda-chlorine plant under the Indo-German Industrial Cooperation plan.

FREDERICH FICHTER

Professor Frederich Fichter, internationally famous scientist, of Basle, Switzerland, died at Basle on June 6th.

Professor Fichter was one of the eminent scientists of his time and was well known to many members of The Electrochemical Society, which he joined in 1907.

Frederich Fichter was born on July 6, 1869. He attended the University of Basle from 1888–90, and later the University of Strasbourg, where he became assistant to Dr. Rudolf Fittig in 1893 and received the Ph.D. degree in 1894. The following year he returned to the University of Basle as assistant to J. Piccard and continued his work there throughout his life. In 1912 he was appointed full professor and chairman of the Department of Inorganic Chemistry, continuing until his retirement in 1939. During this time 300 papers were published from his laboratory. Many of these appeared in the TRANSACTIONS of this Society.

In 1928 Professor Fichter was guest professor at the University of Birmingham in England. Since its founding in 1918 until 1948, he was editor of the well-known *Helvetica Chimica Acta* and was awarded the Paracelsus Medal in 1947 by that organization. He also served as president of the Union of Swiss Chemical Societies and vice-president of the International Union of Chemistry. His chief fields of interest included oxidation by gaseous fluorine, preparation of molten beryllium, and especially the field of organic electrochemistry.

JOHN M. PEARSON

John M. Pearson, director of production, physical, and development research for Sun Oil Company, died on November 16th at his home in Swarthmore, Pennsylvania. He was 48 years old.

Dr. Pearson joined The Electrochemical Society in 1942 and was active in the Corrosion Division. He was the author of a number of articles on corrosion, and held 15 patents on electrical instruments for measurement and control. In 1948, he received the Frank Newman Speller Award for his work in the corrosion field from the National Association of Corrosion Engineers.

Dr. Pearson was a native of Portland, Oregon. He attended Reed College, later receiving the B.Sc. degree from the University of Chicago, and the Ph.D. degree from the California Institute of Technology.

B. SMITH HOPKINS

B. Smith Hopkins, professor Emeritus of chemistry at the University of Illinois, died at his home in Urbana on August 27th.

Professor Hopkins was born in Owossa, Michigan, in 1873 and received the A.B. and A.M. degrees from Albion College in 1896–97, and his Ph.D. from M.I.T. in 1906. He spent most of his life teaching, with the later years at the University of Illinois where he was Professor of Inorganic Chemistry. He had been a member of The Electrochemical Society since 1922.

JOHN L. BRAY

John L. Bray, 62, professor of metallurgy at Purdue University since 1923, and head of the school of chemical and metallurgical engineering from 1935 to 1947, died at his home in West Lafayette, Indiana, on December 6.

Dr. Bray was born in Millbridge, Massachusetts, in 1890, was graduated from Massachusetts Institute of Technology in 1912, and obtained a doctorate there in 1930. He had eight years' experience with mining companies in Central and South America and British Columbia, and taught for a year at M.I.T. and at Nova Scotia Technical College before coming to Purdue. He was the author of several text books in the field of metallurgy and was a widely recognized authority on this subject. He joined The Electrochemical Society in 1929.

NEW MEMBERS

In December 1952 the following were elected to membership in The Electrochemical Society:

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Robert E. Rowley, State College of Washington, mailing add: Kiona, Wash. (Electronics and Industrial Electrolytic)

LETTER TO THE EDITOR

Regarding Function of Oxygen in Zinc Sulfide Phosphors

Dear Sir:

We desire to make the following comments upon the paper by F. A. Kroeger and J. Dikhoff entitled "The Function of Oxygen in Zinc Sulfide Phosphors."[1]

It is an experimental result, obtained by various authors, that in certain circumstances the ratio of the two kinds of the luminogene centers, respectively responsible for green and blue emission bands, decreases as the copper content of ZnS (Cu) phosphors increases. This result was never questioned and the paper of Kroeger and Dikhoff gives a new detailed confirmation of this influence.

But we have also experimentally ascertained that, with a constant copper concentration of 5.10^{-5} (which, from the work of previous authors, must lead to phosphors containing green centers in important predominance), samples of ZnS (Cu) show either a blue-violet luminescent emission without afterglow, a green luminescent emission with strong afterglow, or an intermediate one.[2] In these various samples characterized by exactly the same concentration of copper, the ratio green/blue centers has a considerable range of variation. We observed that these important differences must be imputed to a variation of the oxidized state of luminogene centers, a center containing oxygen which is green and a center without oxygen which is blue. It seems that Kroeger and Dikhoff have understood that, in our own investigations, we took, as they did, zinc oxide ZnO as oxidizing agent. Actually, our oxidizing agent was oxygen itself, in gaseous state. Under these conditions, very small amounts of O_2, comparable to those of activating copper, were sufficient to obtain a total shift from blue to green.

These results are in good agreement with those of Kroeger and Dikhoff concerning the tendency of oxygen and activating atoms or ions to associate with one another in the lattice. This tendency indicates a kind of chemical affinity, which may alter the energy level of the luminogene centers built with these atoms.

These results also agree with those concerning the influence of the copper content upon the ratio of the green/blue centers, as we shall show with more detail in a later paper which we plan to submit to this Journal. Nevertheless, they indicate that this influence is not a direct one but quite the reverse, an indirect one, through the intermediate oxidization of the activating atoms. The two models Cu^+ and Cu_2^+, respectively proposed for the green and the blue centers, do not seem to fit with the results of our experiments.

Edmond Grillot
and Marguerite Bancie-Grillot
Laboratoire de Luminescence—Faculté des Sciences, P. C. B., Paris, France

[1] F. A. Kroeger and J. Dikhoff, *J. Electrochem. Soc.*, **99**, 144 (1952).

[2] Edmond Grillot and Marguerite Bancie-Grillot, *Compt. rend. l'acad. sci.*, **231**, 966 (1950); Edmond Grillot, *J. chim. phys.*, **48**, 112 (1951).

RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette

September 16, 1952

Wilcock, R. C., and Hastings, P. E., 2,611,008, Circuit Tester for Battery-Energized Circuits

Cade, P. J., and MacDougall, D. J., 2,611,113, Electrolyte Indicating and Control Apparatus

September 23, 1952

Koch, H. E., 2,611,790, Electric Heat Treating Furnace

Brandau, W. E., 2,611,791, Thermocouple Means

André, H. G., 2,611,792, Method of Making Electric Accumulators

Simpson, A. W., 2,611,793, Dry Cell with Improved Thermoplastic Seal

Peterson, J. L., 2,611,794, Terminal Assembly for Electric-Cell Batteries

Kerby, W., 2,611,853, Battery Heater

September 30, 1952

Andrus, O. E., Re. 23,559, Corrosion-Resistant Metallic Structure

Reisinger, F. F., 2,612,469, Rapid Fine-Grained Copper Electrodeposition

Griess, J. C., Jr. and Rogers, L. B., 2,612,470, Selective Electrodeposition of Silver

Standing, S. A., 2,612,476, Luminescent Screen for Image Reproducing Tubes

Heise, G. W., and Schumacher, E. A., 2,612,532, Primary Cell or Battery

Blake, I. C., 2,612,533, Primary Cell; 2,612,534, Primary Cell; 2,612,535, Primary Cell; 2,612,536, Primary Cell; 2,612,537, Primary Cell

Cahoon, N. C., and Heise, G. W., 2,612,538, Primary Galvanic Cell and Battery and Method of Making Same

Dyer, C. A., 2,612,539, Cell and Support

October 7, 1952

Mulford, S. F., 2,612,779, Compensated Thermocouple

Grant, A. W., 2,613,178, Method of Electroforming Seamless Tubes

Wolfson, H., and Thomson, B., 2,613,179, Silver Plating

Eppley, M., 2,613,234, Plug or Septum for Electrolytic Cells

Christie, S. L., 2,613,248, Battery Testing Apparatus and Method

October 14, 1952

Mackey, R. W., and Swalheim, D. A., Application 105,447, Current Reversal Electroplating

Lloyd, R. R., and Rosenbaum, J. B., Application 238,361, Electrolytic Diaphragm Cell

Taylor, H. L., and Hedding, L. K., 2,614,052, Manufacture of Copper Oxide Rectifiers

Smith, A. L. J., 2,614,082, Zinc Sulfide Type Phosphors Containing Magnesium Sulfide

Jacquier, P. A. C., 2,614,138, Sealable Storage Battery Construction

October 21, 1952

Tanczyn, H., 2,614,921, Stainless Steel and Method

Loosjes, R., and v. Genuchten, A. J., 2,614,942, Thermionic Cathode

Proudfoot, C. B., 2,614,946, Granular Silicon Carbide and Method of Making Same

Heyroth, A. H., 2,614,947, Refractory Articles and Method of Making

Chester, A. E., 2,164,975, Electroplating of Zinc and Electrolyte Therefor

Patnode, H. W., and Wyllie, M. R. J., 2,614,976, Electrode for Determining Cationic Activity

Marinace, J. C., and Le Loup, T. E., 2,615,060, Crucible for the Purification of Molten Substances

LITERATURE FROM INDUSTRY

TEMPERATURE RECORDER DATA. New 20-page bulletin just issued by manufacturer of industrial instruments for the measurement and control of process variables, contains complete details of temperature recorder construction, showing how each component part, from bulb to chart, contributes to recorder accuracy. Includes more than 50 photographs, charts, and diagrams. The Foxboro Co. P-105

OIL-FILLED ACCELEROMETER. A new accelerometer, No. 24133, has been announced. Compactly designed to fit in an oil-filled case, it is extremely resistant to vibration and has long life-expectancy. It utilizes a potentiometer resistance with a large output, requiring no amplifying unit in most cases; has low, natural frequency. Designed for applications in computing, telemetering, and aircraft missile control. G. M. Giannini & Co., Inc. P-106

ELECTRODE RAPPING SYSTEM. Booklet with illustrated information on the recently developed M.I. (magnetic impulse) continuous electrode rapping system for electrostatic precipitators has been announced. The M.I. rapping system is a continuous, self-monitoring electrode cleaning system that improves over-all precipitator efficiency and reduces operating costs. Research Corp. P-107

CONTROL CENTER BOOKLET. New 31-page application booklet on control centers stresses the case for centralizing all controls of an entire system in one group of enclosures. Also discussed are characteristics of control centers that make for flexibility of application, ease of servicing, and safety of operating personnel. Three types are described and the various electrical components that make up typical units are illustrated and defined. Westinghouse Electric Corp. P-108

AUTOMATIC VOLTAGE STABILIZERS. New 12-page, two-color booklet on automatic voltage stabilizers ranging from 15 to 5,000 volt amperes is available. Contains photographs and diagrams of the equipment, explains operation principles and construction, and gives complete specifications. General Electric Co. P-109

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THE NIAGARA FRONTIER

General Introduction

Paul S. Brallier[1]

Historically, the Niagara Frontier has been the heart of the electrochemical industry in the United States. Early exploitation of processes for making calcium carbide, silicon carbide, graphite, aluminum, magnesium, and sodium gravitated to this area primarily because of the availability of large blocs of cheap power. This power plus important and accessible deposits of rock salt within 70 miles made it a natural center of the chlor-alkali industry. Heavy concentration of consumers of these electrochemical products north of the Potomac and Ohio Rivers and east of the Mississippi made Niagara a convenient and economical shipping center. Cheap and abundant power, however, was the main factor in its early growth.

When the power demand exceeded what could be developed from permissible water diversion, necessitating the generation of supplemental steam power, further electrochemical expansion drifted to the Ohio and Kanahwa Valleys and other centers where fuel was cheaper. Chlor-alkali centers sprang up near other salt deposits in Ohio and Michigan, and, eventually, in Texas and Louisiana.

The dispersive trend of the electrochemical producing industries was hastened by a parallel trend to dispersion of industries consuming these products into the south and southwest, and more recently into the Central states, and by the mounting impact of shipping charges as freight rates increased. These influences were especially pronounced in the case of chlor-alkali because of the rise and growth of the synthetic organic chemical industry and its close association with natural gas and petroleum.

While tonnage-wise, Niagara industries are now dwarfed by some of their widely scattered offspring, the frontier continues to be an active research and development center for electrochemical and electrothermal operations. Possibly several generations of working with such processes has developed an indigenous capacity for this type of work which speeds the progress of experimental programs related to it.

Power, however, continues to be the dominant factor in the industrial growth of the region. The initial hydroelectric generating capacity of 80,000 kw on the American side grew to 304,000 kw within the first 25 years of operation, and stopped there for the succeeding 20 years because that was the limit that could be obtained from the volume of water permitted to be diverted for power purposes by international treaty. Growth in power supply during those two decades came from increasing steam-generating capacity near Buffalo on the Niagara River which, by 1940, had reached about 465,000 kw. American hydro was supplemented during most of this period by surplus hydro power from stations on the Canadian side of the river.

The emergency of World War II led to increased water diversion by both U. S. and Canadian operators which added 110,000 kw to the American hydro supply, and permitted expansion of hydroelectric plants in Canada. The growth of power-consuming industries in Canada, however, absorbed all of their larger output and took most of the surplus hydro power that had been transmitted across the border. The Niagara Mohawk Power Company has installed 160,000 kw of new steam-generating capacity during the war and postwar years and has relieved the Niagara River stations of part of the western New York load by installing 160,000 kw of steam capacity at Dunkirk, New York, on Lake Erie. The present western New York supply stands approximately as follows:

414,000 kw	total American Niagara hydro
16,000 kw	miscellaneous western New York hydro
80,000 kw	imported Canadian hydro
625,000 kw	steam power at Buffalo
160,000 kw	steam power at Dunkirk
1,295,000 kw	

"Redevelopment" of the Niagara River power stations to permit greater power generation without impairment of the scenic beauty of the Falls has been in the minds of engineers on both sides of the river for the past 35 years. A greater percentage of stream flow may be diverted without scenic impairment by suitable distribution of the flow across the crest of the Falls. Much greater power output per cubic foot of water diverted can be obtained by locating the generating stations near the lower end of the Niagara Gorge to get more nearly the full hydraulic head of the water.

Brief accounts of the Canadian program for increased power generation, which is now in the active construction stage, have already been referred to in various issues of the JOURNAL. Corresponding plans have been fully developed by engineers of the Niagara Mohawk Power Company and its predecessors for the American share of the water to be diverted. These plans look to the generation of an additional 1,200,000 kw of hydro power. Five New York State utilities stand ready to finance and construct the necessary facilities, and have made formal application to the Federal Power Commission for permission to do so. Action on the application, however, has been held up pending the completion of engineering studies by the U. S. Army engineers, and pending a decision as to whether the installation is to be done by the Federal Power Commission, the New York State Power Authority, or the group of privately owned utilities, whose rate structures are under the control of the New York State Public Service Commission. The status of the Niagara River as an international boundary stream does not lessen the complications involved.

In the following three papers, an effort has been made to describe the postwar developments in the electrochemical, electrometallurgical, and chemical industries of the Niagara Frontier. Morton S. Kircher, of the Hooker Electrochemical

[1] Stauffer Chemical Company, New York, New York.

Company, tells of electrolytic and chemical operations in the Niagara Falls area. William T. Dunlap, of the Electro Metallurgical Company, Division of Union Carbide & Carbon Corporation, gives an account of the Niagara Falls electrothermal industries. Gordon R. Finlay and J. A. Upper of the Norton Company, Chippawa, Ontario, describe developments in the abrasives industry on the Niagara Frontier. A supplementary article on the chemical and electrochemical process industries of the Buffalo area will appear in a later issue of the JOURNAL.

POSTWAR INDUSTRIAL ELECTROCHEMICAL AND RELATED CHEMICAL DEVELOPMENTS IN THE NIAGARA AREA

M. S. Kircher[1]

The prime reasons for the establishment of electrochemical industry at Niagara Falls a half-century ago were the availability of cheap and abundant power and the relatively good location with respect to markets and raw materials. The general situation with respect to raw materials and markets has not changed greatly, but power for expansion during the postwar years has not been exceptionally cheap or abundant. Hence new developments have been limited largely to modest expansion, integration, and development of new products and processes which fit the economy of the area. It is the purpose of this article to briefly outline this growth.

The chemical industry at Niagara Falls is based largely on the electrolysis of salt, the electric furnace production of calcium carbide, and, to a lesser extent, on the electric furnace production of phosphoros. From the primary raw materials, salt, potassium chloride, coke, limestone, and phosphate rock, none of which are produced at Niagara, the electrochemical industry produces such basic chemicals for the chemical industry as chlorine, caustic soda, caustic potash, sodium chlorate, hydrogen, sodium metal, sodium amalgam, hydrogen peroxide, acetylene, cyanamide, phosphoros, and phosphoric acid.

The electrolysis of salt is considered to include the electrolysis of potassium as well as sodium chloride and embraces such varied processes as the electrolysis of fused salt to produce chlorine and sodium metal; the electrolysis of brine by the diaphragm process to produce caustic soda or caustic potash, and chlorine and hydrogen; the electrolysis of brine by the mercury cell process to produce sodium or potassium amalgam (which are reacted with water to form caustic soda or caustic potash), chlorine and hydrogen; and the electrolysis of brine without a diaphragm to produce chlorates and perchlorates.

The diversification in the uses of chlorine is one of the most interesting accomplishments and one of most vital importance to the development of chemical industry at Niagara Falls. The versatility of chlorine as a chemical reagent together with its relatively low cost has resulted in a mushrooming derivatives industry. It is estimated that more than 75 per cent of the 800 tons of chlorine produced per day at Niagara is used locally in the manufacture of a hundred or more chlorine derivatives including carbon tetrachloride, chlorbenzenes, trichlorethylene, perchlorethylene, benzene hexachloride, monochloracetic acid, chlortoluenes, chlorparaffines, and polyvinyl chloride.

Acetylene which is one of the traditional building blocks of organic synthesis has equally interesting possibilities and it is natural that many of the larger volume chemical products at Niagara are based on both chlorine and acetylene. At least six major acetylene pipelines feed Niagara's chemical industry from the large plant of the Electro Metallurgical Division of Union Carbide and Carbon Corporation. Among the principal acetylene derivatives produced at Niagara are: polyvinyl chloride, vinyl acetate, polyvinyl alcohol, trichlorethylene, perchlorethylene, acetic acid, and monochloracetic acid.

Hydrogen utilization, although not as important or as diversified as chlorine and acetylene, exemplifies the degree of integration of the area. There are probably a dozen interplant pipelines conveying hydrogen for such purposes as: the manufacture of synthetic high-purity hydrogen chloride for vinyl chloride manufacture; synthesis of hydrogen sulfide for high-purity sodium sulfide and sodium sulfhydrate manufacture; compression into cylinders for sale; hydrogenation of furfural to furfuryl alcohol; hydrogenation of furan to tetrahydrofuran; hydrogenation of phenol to cyclohexanol; hydrogenation on a medium or small batch scale of dozens of organic compounds; manufacture of synthetic ammonia; and reduction of mill scale to pure powdered iron for powdered metallurgy.

Electrochemical Developments

Two important new chlor-alkali cells have been developed to commercial importance at Niagara Falls during the postwar period, namely the Mathieson "Stationary" mercury cell and the Hooker Type S-3 diaphragm cell. The Mathieson cell, developed by W. C. Gardiner and associates, which is the only modern American mercury cell used on a large scale, when compared with mercury cells of European origin, is characterized by simplicity, a minimum of gadgets, and relatively low construction cost (1). The Mathieson cell has been installed in two large new Mathieson plants and in the plant of a licensee.

The Hooker Type S-3 and its modification the S-3A, which are rated at 20,000 and 25,000 amperes, respectively, are identical excepting that the S-3A has been rotated 90° and provided with heavier copper conductors (2). The S-3 and S-3A, like the older Hooker Type S, are based upon the use of a deposited asbestos diaphragm. These cells cut floor space and operating labor requirements approximately in half as compared with the smaller type S cell. Two Niagara Falls plants, Hooker Electrochemical Company and Stauffer Chemical Company, have installed S-3 cells in making substantial expansions. In addition the new cells have been installed in four other large plants in the United States during the past five years.

A major expansion and modernization program at Stauffer Chemical Company has made it one of the major chlorine caustic producers in the area.

The Niagara Alkali circular-type diaphragm cell has been further improved and a recent substantial expansion at the

[1] Hooker Electrochemical Company, Niagara Falls, New York.

Rotkin, P. F. I.

View of the Mathieson Stationary Mercury cells at McIntosh, Alabama; these cells were piloted at Niagara Falls.

Niagara Alkali Company's plant has been made with this cell.

Although there seem to have been no recent articles published on Du Pont's Downs fused-salt cell, it may be presumed that considerable work has been done toward the further development of this cell to obtain larger capacity and higher efficiency. A recent patent gives some insight into this development (3).

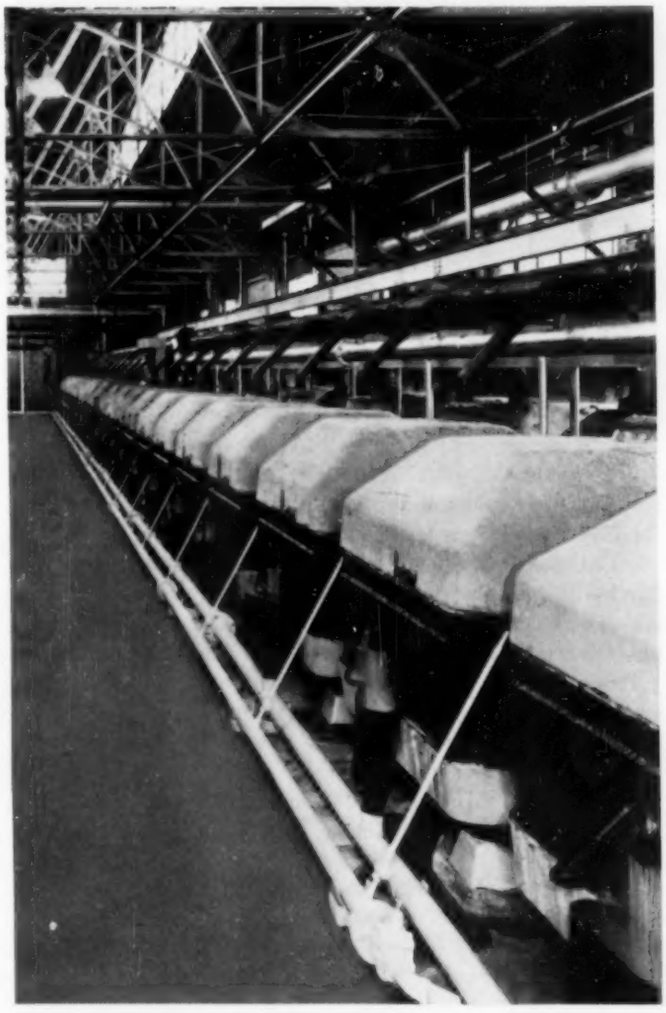
Emphasis on Integration

The most dramatic example of the integration of the electrochemical industry with the newer chemical growth at Niagara is the Du Pont process for the manufacture of adiponitrile, a major nylon intermediate, from furfural (4, 5). The manufacture of nylon "from corncobs" is a dramatic story in itself; however it is probably not generally recognized that integration of the process with the electrochemical industry at Niagara was the key which has permitted this process to be competitive with alternate processes based upon petroleum derivatives.

Following the conversion of furfural to furan by catalytic removal of the side chain, the furan is hydrogenated to tetrahydrofuran employing electrolytic hydrogen which is a by-product of the caustic chlorine industry. Tetrahydrofuran is hydrochlorinated to 1-4 dichlorobutane employing HCl which may be derived from organic chlorination or which may be produced directly from electrolytic hydrogen and electrolytic chlorine. The 1-4 dichlorobutane is converted to adiponitrile by reaction with sodium cyanide. Sodium cyanide also is of electrolytic ancestry, being produced from electrolytic sodium, carbon, and ammonia which is produced from electrolytic hydrogen. Sodium chloride derived as a by-product of the reaction of sodium cyanide with the dichlorobutane is recovered for return to the fused-salt sodium chlorine cells.

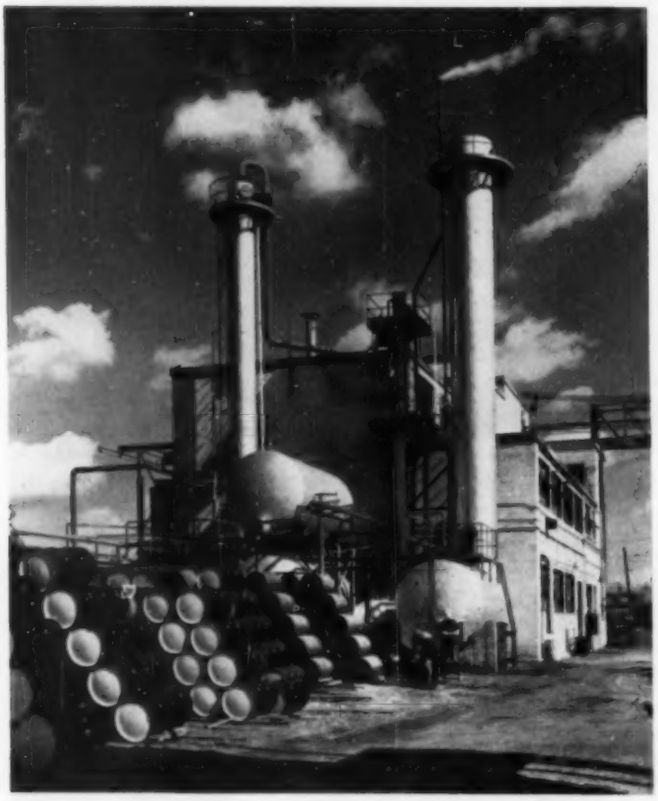
Chemical Developments

In the field of chlorinated organic compounds some of the major developments at Niagara Falls have been the installa-



One group of a double row of Hooker S-3A cells at the Hooker Electrochemical Company's plant.

tion of a trichlorethylene plant by Niagara Alkali Company, a large expansion in the manufacture of carbon tetrachloride by Stauffer, the development and installation of processes for making benzene hexachloride by Hooker Electrochemical Company and by Mathieson Chemicals Corporation, the development of a process for the production of lindane, the pure gamma isomer of benzene hexachloride by Hooker, and the production of monochloracetic acid by Hooker and Stauffer.



The trichlorethylene plant of the Niagara Alkali Company at Niagara Falls.

In the field of acetylene derivatives, mention should be made of the production of polyvinyl chloride and copolymers by Pathfinder Chemical Company and B. F. Goodrich Chemical Company and the development of polyvinyl alcohol by the Electrochemicals Division of Du Pont.

Oldbury Electro-Chemical Company has considerably expanded yellow phosphorous production in conjunction with its increased production of phosphorous pentasulfide, phosphorous trichloride, and phosphorous oxychloride.

Production of caustic soda, the largest heavy chemical export from Niagara, has been greatly expanded by Niagara Alkali, Stauffer, and Hooker and constant progress is being made toward higher purity.

International Minerals and Chemical Company and Niagara Alkali are both producing high purity potassium carbonate. Oldbury Electro-Chemical Company has increased production capacity for sodium chlorate and modernized its perchlorate plant. Two fused-salt processes based on caustic soda for descaling stainless and alloy steels have been developed to widespread commercial use in the steel industry by Niagara Falls companies. Hooker's "Virgo" is an oxidizing process, whereas Du Pont's "Hydride" process depends upon the reducing action of sodium hydride.

Mathieson Chemicals Corporation has further increased the production of calcium hypochlorite (HTH), sodium chlorite, and chlorine dioxide and has developed a process for hydrazine which is of increasing importance as a rocket fuel and intermediate for pharmaceuticals. The Electro Metallurgical Division of Union Carbide and Carbon Corporation has further developed its processes for manufacture of salts of tungsten and vanadium. The Titanium Alloy Manufacturing Division of National Lead Company has also increased development of its line of zirconium chemicals.

Business and Organization Changes

International Minerals and Chemicals Corporation has purchased the Isco Division of Innis Spieden & Company in a further move toward integrating their production of potassium chemicals. Pathfinder Chemical Company, a subsidiary of Goodyear Tire and Rubber Company, has constructed a plant at Niagara for the production of polyvinyl chloride and copolymers. Two consulting organizations, R. B. MacMullin Associates and Maurice C. Taylor Laboratories, have been formed, both of which specialize in electrochemical and related technology. Mathieson Alkali Works has become Mathieson Chemicals Corporation and the company has been greatly expanded, both by purchase of other companies and erection of new plants. New research and pilot plant buildings have been added to the Niagara Falls Plant. The Niagara Falls plant of the Chemical Corps has been reactivated and is being operated by the Hooker Electrochemical Company.

Conclusion

The growth of industrial electrolysis during the past twenty years has resulted very largely from the expansion of the synthetic organic chemical industry. The integration of industrial electrolysis with synthetic organic chemical production has been a major factor in the growth of Niagara Falls as an industrial center. Because it is the birthplace and greatest seat of industrial electrochemistry, Niagara has become a center for industrial research, consulting, and licensing of electrochemical processes.

The proposed further expansion of hydroelectric power generation at Niagara may be expected to give further impetus to its electrochemical and allied industries.

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RECENT DEVELOPMENTS IN THE FERROALLOY AND CARBON INDUSTRIES

W. T. Dunlap, Jr.[1]

The ferroalloy industry which started in Niagara Falls about forty years ago has grown rapidly and is now thriving in the north, south, east, and west. This dispersion of the industry has been occasioned by availability of power, nearness to raw materials and markets, labor supply, and strategic reasons. The growth of this industry has been at a rather regular rate, approximately tripling its size every fifteen years. The ferroalloys largely go into the manufacture of steel, but because of increased usage of alloys per ton of steel or, to express it another way, because of the increased production of stainless and other high alloy steels, the ferroalloy industry has expanded over 200 per cent since the start of World War II while the steel industry has expanded about 45 per cent during the same period of time. Just prior to World War II, about 6 per cent of the steel produced was alloy steel; during the war alloy steels jumped to about 10 per cent and is currently running about 8 per cent of the steel produced. It is estimated that steel capacity by the end of 1953 will be 120,000,000 ingot tons as compared to 104,000,000 at the end of 1951. At the beginning of the war it was about 82,000,000 ingot tons.

The ferroalloy industry is represented in the Niagara area by the Niagara Falls, New York, and Welland, Ontario, plants of the Electro Metallurgical Company; plants of Pittsburgh Metallurgical Company; Titanium Alloy Manufacturing Division of National Lead Company; and Vanadium Corporation of America. The principal products of these plants are alloys of chromium, silicon, manganese, columbium, tungsten, titanium, zirconium, cobalt and vanadium, and calcium carbide.

Technological progress has continued at an accelerated rate in the ferroalloy industry with emphasis on the production of better quality alloys and pure metals. The Niagara Falls ferroalloy industry takes pride in the part it has played in the development of lower impurity ferrosilicon, lower carbon grades of ferrochromium and chromium metal, and titanium and zirconium metal. The lower carbon grades of ferrochromium and chromium metal help to make possible the manufacture of the alloys for severe service, such as jet and turbo-jet engines, and also aid in the conservation of strategically important columbium, since the use of columbium is directly proportional to the carbon content. Research is making rapid progress in this industry and many new developments may be announced in the near future.

During the last six or seven years, a considerable program of plant modernization has taken place at Niagara Falls. Ferro alloy plants in this area are now equipped with the most modern and efficient types of electric furnaces and, together with the new plants at other locations, are capable of supplying any foreseeable alloy requirements as measured by steel capacity, in case of national emergency.

Another major development during the postwar period has been work on fume and dust abatement and on the lessening of stream pollution. Noteworthy progress has been made and Niagara Falls is now a cleaner place in which to live.

The history and development of the carbon industry in the Niagara area closely parallels that of the ferroalloy and carbide, and the electrochemical industries. This industry is represented in this area by the Acheson Graphite Company; National, Republic and Welland plants of the National Carbon Company; International Graphite and Electrode Division of Speer Carbon Company; and Great Lakes Carbon Corporation.

The products manufactured include carbon and graphite electrodes, anodes, crucibles, and special shapes for all electrothermic, electrolytic, and special metallurgical and chemical applications. Continued research is carried on to improve the products of this industry and to develop carbon products for new applications. Structural shapes, kiln and blast furnace linings, and metal chills are some of the relatively new applications.

The carbon industry in Niagara Falls, as well as the ferroalloy industry, has just completed a postwar modernization program including smoke abatement.

The ferroalloy and carbon industries in the Niagara area are alive, vital, and bustling. Niagara Falls industries have had a major part to play in the expansion of these industries as a whole, and it can confidently be expected that they will continue to expand.

[1] Electro Metallurgical Company, Niagara Falls, New York.

DEVELOPMENTS IN THE ABRASIVES INDUSTRY IN THE NIAGARA AREA, 1945 TO 1953

G. R. Finlay and J. A. Upper[1]

The postwar period in the abrasives industry has been marked by numerous changes. This article proposes to describe some of the developments and advances which have occurred in the Niagara area since the year 1945. The manufacturers of synthetic abrasives were drawn to Niagara by the availability of cheap hydroelectric power. Some finishing plants followed the supply of crude abrasives, so that the region has become the heart of the synthetic abrasive industry.

[1] Norton Company, Chippawa, Ontario.

Plant Expansion and Capacity

The capacity of the industry has been greatly increased; some of the older plants and buildings have been thoroughly remodelled and considerable new construction has taken place. Lionite Abrasives has built a new silicon carbide plant in Stamford, Ontario, with complete storage facilities for raw materials. This plant was put in operation in March 1950 and has an ultimate capacity of 8000 tons per year. Lionite is now expanding its aluminum oxide capacity by six furnaces, an increase of 60 per cent. General Abrasives Company, the

parent company of Lionite, has refitted the plant at Niagara Falls, New York, and this has also undergone expansion. The Exolon plant at Thorold, Ontario, has added 12,000 tons annually to its electric furnace capacity for manufacture of crude, fused aluminum oxide abrasives. At the same time the company has converted all its furnaces to 60-cycle operation. The grain processing plant for silicon carbide, which Exolon formerly operated at Blasdell, New York, was closed in 1947 and operations were transferred to their headquarters in Tonawanda. There, the facilities for processing both silicon carbide and fused alumina have been completely modernized. The Carborundum Company has made numerous changes in its plant and laboratories at Niagara Falls, New York, and a complete refitting of the laboratory is now being planned. Carborundum also purchased from the Bell Aircraft Corporation a plant at Wheatfield, New York, which was converted to the production of coated abrasives and opened in 1945. In 1949 a plant was set up to produce fused, cast refractories at Falconer, New York. Electro Refractories and Abrasives Company is just completing a new $750,000 plant in Buffalo for the production of grinding wheels. The company has also doubled its capacity for processing refractories and is setting up a new tunnel kiln. Other new construction includes a grain processing plant and a new shipping building.

The Norton Company has added to its facilities a completely modern, new research laboratory at Chippawa which was opened in 1947. It has also doubled its capacity for the production of fused magnesium oxide and further expansion is under construction. Two new units have been added to the aluminum oxide electric furnace plant, along with supporting facilities. Other new construction at Chippawa includes a 32 Alundum plant, and a Raymond Mill crushing plant. The Norton Company of Canada, at Hamilton, has been gradually converting from the old bottle-type kilns to the more modern tunnel kilns and this program is now substantially complete.

When it became necessary to secure calcined bauxite from South America rather than from Arkansas, both Norton Company and Carborundum found it necessary to increase their storage facilities considerably. Both companies constructed batteries of concrete silos sufficient to store about five boatloads of ore, i.e., 30,000 tons of calcined bauxite.

As noted above, the capacity of the industry has been considerably increased. Power shortages, power interruptions, and increased costs have impelled some of the producers to locate new plants elsewhere. Silicon carbide, as a relatively large consumer of power, was the logical choice for displacement. The Carborundum Company constructed a new silicon carbide plant at Vancouver, Washington. Electro Refractories and Abrasives and Norton Company have both established silicon carbide plants at Cap de la Madeleine, Quebec. Since the Lionite plant is new, and Exolon has expanded, all five companies now have new capacity for silicon carbide. The Exolon expansion is estimated at a 50 per cent increase. Carborundum Company reports that capacity for silicon carbide and fused aluminum oxide has been doubled since 1945. No further expansion of silicon carbide capacity is currently in prospect. However, the Norton Company is continuing to expand its aluminum oxide capacity, which has increased approximately 50 per cent since 1945.

Somewhat apart from the abrasives industry, although growing out of it, is a new venture of the Carborundum Company. It has formed a subsidiary called the Carborundum Metals Company; a plant is being built at Akron, New York, to pro-

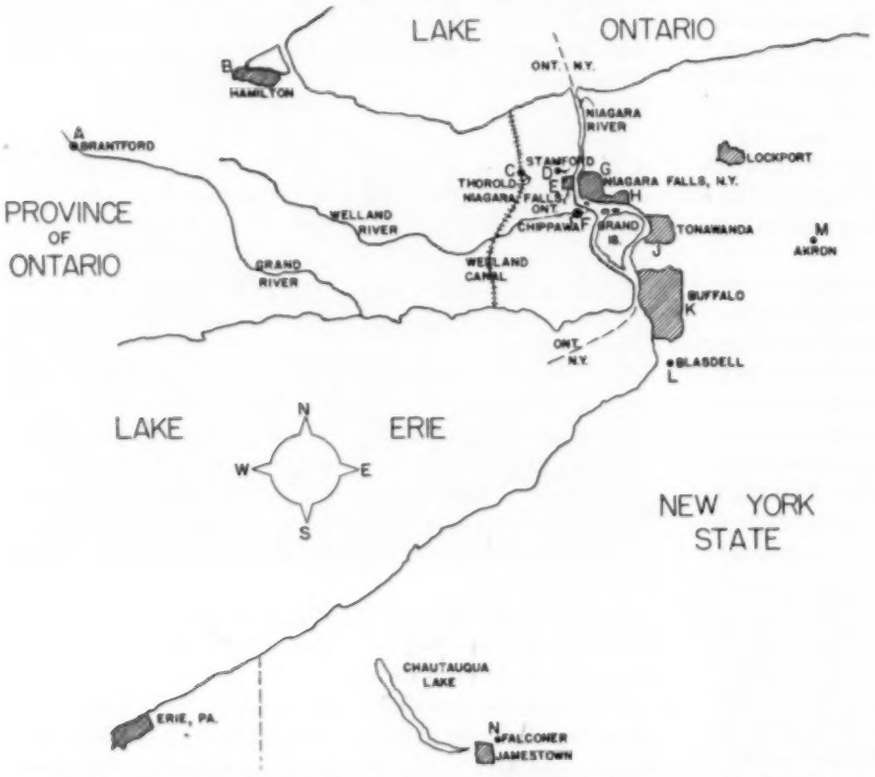


FIG. 1. Map of the Niagara border area showing locations of the various abrasives plants.

Key to map: A—Norton Behr-Manning Overseas, Inc., coated abrasives plant; B—Norton Company of Canada, Ltd., grinding wheel manufacturers; C—Exolon Company, crude abrasives plant; D—Lionite Abrasives, Ltd., crude abrasives; E—Canadian Carborundum Company, Ltd., crude abrasives and grinding wheels, etc.; F—Norton Company, crude abrasives and refractories; G—General Abrasives Company; H—Main plant of Carborundum Company, crude abrasives and refractories, grinding wheels, etc. Coated abrasives plant at Wheatfield, New York, adjoining city of Niagara Falls, New York; J—Exolon Company, abrasive grain treating plant, magnetic separators, etc.; K—Electro Refractories and Abrasives Company, abrasive grain treating plant, grinding wheels, refractories, etc.; L—Former silicon carbide grain treating plant of Exolon Company; M—Carborundum Metals Company, zirconium sponge; N—Carborundum Company, fused cast refractories.

duce 150,000 lb of zirconium sponge per year for the Atomic Energy Commission.

These increases in capacity have naturally called for a considerable increase in personnel. In addition to the production staff required, both Carborundum and Norton have added considerably to their laboratory and research staffs. Both General Abrasives and Electro Refractories and Abrasives have appointed directors of research, and, no doubt, plan further expansion of their technical staffs.

Process Improvements

The most striking postwar development in the production of aluminum oxide is the technique of pouring and casting this material. Procedures for casting white Alundum are described in patents issued to E. Van der Pyl and J. A. Upper of Norton Company. A somewhat different technique is being employed by the Carborundum Company for the casting of its standard aluminum oxide product. Although experimental products were made by pouring and casting as early as 1910, it has only recently been possible to carry out this operation on a commercial scale.

New Products

Among the new products which have come on the market since 1945, the cast aluminum oxide produced by Norton Company and Carborundum Company is, tonnage-wise, by far the most important. Norton Company's 32 Alundum has also been a large-scale product. Other new materials which are now being produced on a plant scale are: Fiberfrax (Carborundum Company), fused stabilized zirconia, fused calcined dolomite, and grade 368 Norbide (boron carbide with excess boron). The last three items are products of the Norton Company. As noted above, the Carborundum Company is going into the production of zirconium and hafnium metals on a plant scale. As an intermediate in this process, they are now producing zirconium carbonitride. Although this has long been made by the Titanium Alloy Manufacturing Division of National Lead Company, it is a new product with the Carborundum Company.

The fused cast refractories produced by Carborundum at Falconer include glass tank blocks, steel furnace refractories, and materials for wear-resistant applications such as ball-mill liners.

FIG. 2. New research laboratory of the Norton Company at Chippawa, Ontario

Arc furnace methods of fusion have been applied to the following materials: lime, dolomite (CaO·MgO), thoria, and stabilized and unstabilized zirconia. Arc furnace techniques for the production of boron carbide, titanium carbide, zirconium carbide, and zirconium carbonitride have also been improved considerably. Another postwar development has been the Norton Company's commercial production of crystal alumina or 32 Alundum. This process was developed prior to the war but was not put in commercial operation until December 1945.

Considerable work has been done on the air blowing of molten materials. This has recently culminated in the production of Fiberfrax ceramic fiber which is now being manufactured by the Carborundum Company on a semicommercial scale. This alumina-silica fiber shows promise of being an excellent refractory.

Another new development in the manufacture of grinding wheels has been the adoption of forming by automatic presses, followed by a rapid firing in an electrically heated kiln. This automatic process has been applied by the Norton Company to the manufacture of large quantities of the smaller sizes of grinding wheels.

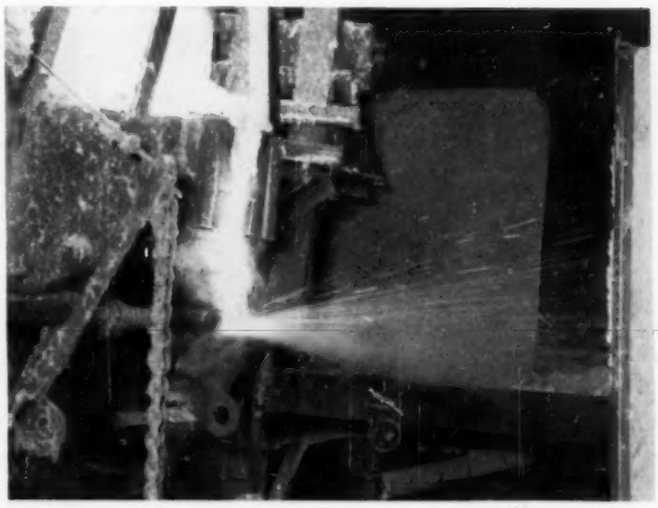


FIG. 3. Tapping of furnace to produce Fiberfrax at the Carborundum Company plant.

In the field of refractories, the Carborundum Company has introduced the Niafrax line, which is a silicon carbide

bonded with silicon nitride, rather than with the usual clay-type of bond. Their Refrax silicon carbide is a related product.

Both Norton and Carborundum have been producing boron nitride on a pilot plant scale. Norton Company has produced titanium carbide and zirconium carbide on a semicommercial scale, while zirconium boride and a variety of other carbides and borides are still being made on a laboratory scale. Carborundum Company has also been working with zirconium boride and silicon nitride.

For a number of standard products there has been a sharp increase in demand since 1945. Some of this increased demand has resulted in the new capacity discussed earlier. The consumption of fused magnesium oxide has increased very considerably. The refractory and metallurgical uses of silicon carbide have also expanded and both the Carborundum Company and Electro Refractories and Abrasives report a considerable increase in demand for their metallurgical addition agents. There has also been an increased demand for special grades of silicon carbide to be used as lightning arrester grain or for other electrical devices. The production of green silicon carbide has grown, along with the growth of the cemented carbide industry, since green wheels are preferred for sharpening carbide tools.

Norbide (Norton boron carbide) has been found to be an excellent absorber for neutrons and this new use has added to the demand for this material. Boron carbide has also been used as a raw material for the manufacture of high quality boron trichloride.

Changes and Reorganization

An antitrust suit in the United States' courts compelled the dissolution of the Canadian Durex Abrasives Company. This had been a pooled organization among several abrasives companies to serve the Canadian market. The original Durex plant in Brantford has now been taken over by Norton Behr-Manning Overseas, Inc. The Minnesota Mining & Manufacturing Company has set up its own establishment in London, Ontario. Carborundum Company has dispersed its activities among Niagara Falls, Etobicoke, and Preston (Canada Sandpaper).

The Electro Refractories and Alloys Company of Buffalo, New York, has recently changed its name to Electro Refractories and Abrasives. This change brings the concern's name more into line with its activities, since one of its major products is now resinoid-bonded grinding wheels.

Future Developments and Forecasts

No company now in the industry is likely to add to its capacity for the manufacture of either silicon carbide or aluminum oxide in the near future, except for the construction now underway but not yet completed at Lionite and Norton Company. In both these cases the facilities now under construction are for aluminum oxide. As noted before, the Carborundum Company plans to provide expanded research facilities in one of its existing buildings.

Even at the present time, most of the raw materials used in the industry come from great distances. The St. Lawrence seaway may eventually result in more extensive shipments of raw materials by water. Bauxite, for example, could be laid down in the Niagara Peninsula directly from South America.

The government stockpiling program, now in operation, is expected to keep all aluminum oxide crude abrasives plants operating at capacity for at least two years.

Current Affairs

New York Meeting Combines Fine Technical Program with Attractive Entertainment Features

Final arrangements for the Society's ew York Meeting, April 12 through , have been completed, according to eports from General Chairman H. R. opson. The result is an extensive tech- al program, varied entertainment, d a number of special features of usual interest. The Statler Hotel, at h Avenue and 33rd Street, New York, ill be convention headquarters.

Requests for reservations should be nt to Front Office Manager, Hotel tler, and members are urged to make eir reservations early.

egistration

The registration desks will be located the mezzanine floor of the hotel on e south side. Registration hours will gin on Sunday, April 12, from 4:00 M. to 10:00 P.M.; Monday, April 13, om 8:00 A.M. to 5:00 P.M.; and for the maining days of the meeting, 9:00 M. to 5:00 P.M.

Technical Program

The technical program will run from Monday through Thursday, with simultaneous sessions each day. About 135 papers will be presented. Participating are the Theoretical Electrochemistry Division, the Electronics Division, the Electrothermic, Electric Insulation, and Electro-Organic Divisions.

A feature of special interest this year is the 3-day symposium on the Application of Electrochemistry to Biology and Medicine, sponsored by the Theoretical Division. The extensive Electronics program includes symposia on Luminescence, Screen Application, Rare Metals, and Semiconductors. The Electric Insulation Division plans sessions on Electrophysics, Applied Dielectrics, Capacitors, and Electric Insulation.

Another feature of wide interest is the Richards Memorial Lecture which will be held on April 15. The lecture will be given by Dr. William Shockley of Bell Telephone Laboratories on the subject "Transistor Physics."

Round-table discussions have been scheduled by the Luminescence Section and the Phosphor Screen Application Section of the Electronics Division, and by the Electro-Organic Division.

KENNETH G. COMPTON
Chairman, Advisory Committee

The complete technical program will be printed in the April JOURNAL.

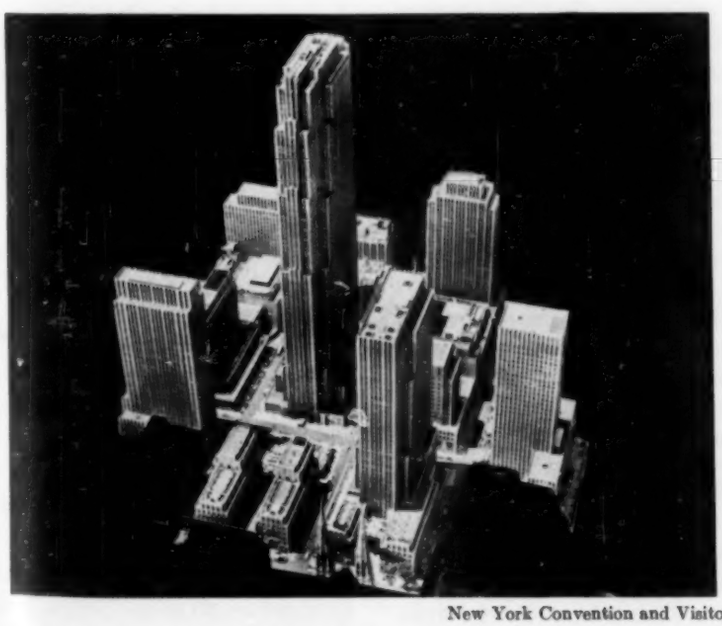
Luncheons

Division luncheons have been scheduled by the Electronics, Electrothermic, Electro-Organic and Electric Insulation Divisions. The latter has planned a special luncheon in honor of Dr. Debye.

The Society Luncheon, to which the ladies are invited, will be held on Monday, April 13, in the Keystone Room. Dr. John R. Dunning, Dean of the School of Engineering, Columbia University, will address the Society on the subject "Engineering Comes of Age."

Entertainment and Dinners

A reception and dinner will be held on Monday evening, April 13, in connection with the symposium on Application of Electrochemistry to Biology and Medicine.



New York Convention and Visitors Bureau

Unusual aerial view of the buildings that comprise the famed Rockefeller Center, one of New York's magnificent sights.

The Reception and Banquet will take place on Tuesday evening; this will be the occasion of the Presidential Address and the awards of the Young Authors' and Turner Book Prizes. A reception for Dr. and Mrs. Warner will precede the Banquet.

Wednesday evening has been left open so that all attending the meeting will be free to enjoy some of the entertainment and dining places the city offers.

For the Ladies

The Ladies Headquarters Room on the mezzanine floor is an innovation designed to enable the ladies to keep posted on all the events planned for their entertainment and to get together for arrangement of group plans.

Fabian Bachrach

FRED P. PETERS
Chairman, Publicity Committee

HERBERT BANDES
Chairman, Entertainment Committee

Prize Essay Contest Announced

The third annual Prize Essay Contest, sponsored by The Electrochemical Society, has been announced and the following subject for the contest selected, "Contributions of Electrochemistry in Science."

Two prizes will be awarded for the two best essays submitted: the first prize will be $100 plus a one-year membership in the Society; second prize will be $50, together with a one-year Society membership. The contest is open to undergraduate and graduate students. Essays, from 1000 to 2000 words, must be received at the Society offices by July 1, 1953. Winners will be announced in the JOURNAL in the October 1952 issue.

The prizes for the contest are financed by royalties received from the sale of the "Corrosion Handbook," a widely used technical publication sponsored by the Society and published by John Wiley & Sons, Inc., in 1948.

Further information concerning the contest may be obtained by writing the Secretary of The Electrochemical Society, 235 West 102nd Street, New York.

Change of Address

Argonne National Laboratory, formerly located in Chicago, Ill., is now addressed at P.O. Box 299, Lemont, Ill.

Nominations Accepted for 1954 Acheson Award

Ernest G. Enck, Chairman of the Acheson Medal Award Committee, would like to receive suggestions for possible candidates for the next Acheson Medal Award, to be made in the fall of 1954.

The procedure to be followed by the membership, taken from the Rules Governing the Award of the Acheson Medal, is given below:

(1) Nominations shall be accepted from the membership at large.

(2) All nominations, whether made by a member of the Nominating Committee or by any other member of the Society, must be accompanied by a full record of qualifications of the nominee for the award. Such supporting documents from friends of the candidate or from his organization shall be in order.

(3) The nominator must assume the responsibility for providing the Chairman of the Nominating Committee with nine copies of the supporting documents, one for each member.

Nominations must be sent to the Chairman not later than March 1st of the year in which the medal is awarded and nominations will be considered closed after that date.

All nominations of candidates for the medal shall be continued in force for a period of two consecutive awards of the medal. Any unsuccessful candidate may be renominated in the usual manner for any subsequent Medal award.

Correspondence should be addressed to Ernest G. Enck, Foote Mineral Company, 18 West Chelten Avenue, Philadelphia 44, Pennsylvania.

Naval Research Lab Announces Vacancies

The Naval Research Laboratory of Washington, D. C., has announced a number of professional vacancies in the physical sciences and engineering fields for which the Laboratory desires applications.

Included in this list of positions to be filled are the following: Electrical Engineers, salaries from $3410 to $5940 per year; Electronic Engineers; Mechanical Engineers, salaries from $3410 to $5940; a large number of Electronic Scientists in various fields; Physicists, salaries $3410–$9600; Laboratory Electronic Mechanics, Metallurgists, and numerous others.

For the majority of the vacancies listed, Civil Service status is not necessary. Interested parties should address inquiries to W. G. Torpey, Personnel Officer, Code 1817, Naval Research Laboratory, Washington 25, D. C.

Abstracts Booklet for Electronics Division

The Electronics Division will again publish an "Enlarged Abstracts" booklet for the 1953 Spring Meeting of the Society at New York. The booklet will have 1000-word abstracts of each paper to be given at the sessions of the Electronics Division in their symposia on *Luminescence*, *Phosphor Screen Application*, *Rare Metals* and *Semiconductors*.

The abstracts will contain pertinent information and experimental data given in the papers and will provide these details before publication, thus aiding workers in the field. The abstracts will be "printed but not published."

The abstract booklets are expected to be available by March 15th; the price will be about $1.50. Orders should be sent to C. W. Jerome, Sylvania Electric Products Inc., 60 Boston Street, Salem, Massachusetts.

Charles A. Thomas Awarded Perkin Medal

Charles A. Thomas, president of Monsanto Chemical Company, was the recipient of the Perkin Medal, considered the highest award in science, at a banquet in his honor at the Waldorf-Astoria Hotel, New York, on January 16.

The Perkin Medal was founded in 1906 in honor of Sir William Perkin on the 50th anniversary of his discovery of the first synthetic dye. It is awarded by the American Section, Society of Chemical Industry, in cooperation with the American Chemical Society, the American Institute of Chemical Engineers, The Electrochemical Society, and the American Section, Societe de Chimie Industrielle. Dr. Thomas is the 47th person to receive the medal.

Dr. Thomas, whose brilliant career includes an impressive list of honors,

CHARLES A. THOMAS

was awarded the Perkin Medal "for outstanding contributions to the chemical technology of automotive fuels, of catalysts, of synthesis of valuable products from petroleum, and of atomic energy."

In his speech of acceptance, Dr. Thomas discussed the disastrous effects that would result from a 50-year cessation or "moratorium" on all scientific activities, a suggestion made recently by some who feared the rapid strides of science. In this connection, the medalist reviewed the ill effects of such a stoppage in the fields of health and medicine, in the losses to industry and the defense program, in employment, and in scientific developments in agriculture affecting food supplies.

International Congress in Paris

The Third International Congress on Electrothermics will be held in Paris on May 18–23, 1953.

About 120 papers will be presented, of which 80 will come from foreign countries. American participation is welcomed and anyone interested in attending the Congress or sending a paper to be read should make application immediately (and submit a 75-word abstract) to Mr. R. Felix, Secretary, III[e] Congres International d'Electrothermie, 2, Rue Henri-Rochefort, Paris (17[e]).

DIVISION NEWS

Electric Insulation Division

The Electric Insulation Division plans to hold a business meeting at the forthcoming Spring Meeting of the Society in New York, during which the election of new officers will take place. The meeting is scheduled for April 15, immediately following the Debye Luncheon.

The following slate has been suggested by the Nominating Committee for the new term:

Chairman—R. A. Ruscetta, General Electric Company

Vice-Chairman—A. Gunzenhauser, Samica Corporation

Secretary-Treasurer—L. L. Deer, Naval Ordnance Plant (Indianapolis)

THOMAS D. CALLINAN, *Chairman*

Electronics Division

The annual business meeting of the Electronics Division will be held during the Spring Meeting of the Society, April 12–16, in New York. The specific time and place will be announced in the Program Booklet for the convention.

Changes in Bylaws

At the Executive Committee meeting of the Division in Philadelphia in 1952, the following changes in our bylaws were proposed:

1. In Article 1, Section 2, and Article 7, Section 2, replace "Fluorescence" with "Luminescence." (This was an error in the original bylaws which is being corrected.)

2. Article 2, add: "Section 3.—Fiscal Year. The fiscal year of the Division shall be from June 1st to May 31st." (Inserted at the request of the Society; we previously had no official fiscal year.)

3. Article 6, Section 1, add "The most recent past Division chairman and the chairmen of symposia shall also be on the executive committee. No member of the executive committee may have more than one vote." (The past Division chairman is included to allow continuity of action. Symposia chairmen are added to better plan their symposia. The "one-vote" addition is made to include a provision implicitly planned when the bylaws were drawn up.)

These changes will be voted on at the business meeting.

* * *

The Nominating Committee, H. C. Froelich, Chairman, S. Jones, and D. M. Wroughton, have selected the following nominees for office during the 1953–54 term:

General Chairman—R. H. Cherry, Leeds and Northrup Company, Philadelphia, Pa.

Group Chairman (Rare Metals)—A. U. Seybolt, Research Laboratory, General Electric Company, Schenectady, N. Y.

Group Chairman (Luminescence)—J. H. Schulman, Crystal Branch, Naval Research Laboratory, Washington, D. C.

Group Chairman (General Electronics)—A. E. Hardy, R. C. A. Victor Division, Lancaster, Pa.

The term of the Secretary-Treasurer, C. W. Jerome, has two more years to run. All nominees have given assurance of their willingness to serve.

The bylaws of the Division provide that additional nominations may be made by petition signed by 5 members of the Division. Such petitions must be in the hands of the Nominating Committee Chairman before the election and the nominees must give assurance of their willingness to serve.

The election will be held at the business meeting of the Division.

C. W. JEROME, *Secretary-Treasurer*

Electrothermic Division

At the meeting of the Nominating Committee of the Electrothermic Division of The Electrochemical Society, held November 12, 1952, the following nominees were selected for the coming election at the Spring Meeting of the Division to be held in New York:

Chairman—I. E. Campbell, Battelle Memorial Institute

Vice-Chairman—John S. Dewar, National Carbon Limited

Secretary-Treasurer—Guy Fetterley, Norton Company

Members-at-Large—Julian Glasser, La Grange, Illinois, and Marvin Udy, Niagara Falls, New York (2 to be elected).

This report is submitted by the Nominating Committee: A. T. Hinckley, Chairman, J. H. Brennan, and H. R. Oswald.

A. T. HINCKLEY, *Chairman*

SECTION NEWS

Cleveland Section

Dr. Robert A. Powers, of the National Carbon Company, Cleveland, addressed a joint meeting of the Cleveland Sections of The Electrochemical Society and the National Association of Corrosion Engineers on January 13 at the Cleveland Engineering Society. Dr. Powers' subject was "Recent Experimental Methods in Corrison Research."

The speaker pointed out that many studies of the fundamentals of corrosion and allied phenomena are in essence the study of surface properties and as such normally permit only an indirect experimental approach. For this reason experimental techniques are perhaps more important than in many other fields of research.

A current trend in corrosion researches of a surface chemistry nature is to study the surfaces in as direct a manner as possible. Two such experimental techniques which allow this were discussed. One was the use of radioactive isotopes as tracers and the other the use of contact difference of potential. The talk was amply illustrated with examples of the use of these two techniques.

J. M. Margolis, *Secretary*

Midland Section

Dr. Roy B. Heath, Consultant in Research and Development of MacDermid Incorporated was the guest speaker at the Midland Section meeting on January 20. His subject was "Electrochemistry in Metal Cleaning."

Both anodic and cathodic cleaning with sodium hydroxide of steel was discussed. The effect of silicates, phosphates, nitrates, chlorides, and other additives to the sodium hydroxide in obtaining clean metal for plating, was presented. The voltage ranges used in the industry as well as the empirical nature of our knowledge of the process, the additives, and the varying nature of the "soil" removed emphasizes, Dr. Heath said, the need for fundamental research on the problems of metal cleaning.

F. N. Alquist, *Secretary*

New York Metropolitan Section

The Metropolitan Section held its first meeting of the new year on January 21st with Dr. Abner Brenner of the National Bureau of Standards as its featured speaker. Dr. Brenner addressed an unusually large gathering on the subject of the "Electrodeposition of Some of the Less Common Metals from Nonaqueous Solutions."

Dr. Brenner stated his belief that all the metals which can be plated from aqueous solutions have been plated and that there is very little hope for another development like that of chromium plating. The real improvements in the future will come in the nonaqueous field, he said. Metals not now plateable from aqueous solutions include two types: the so-called light metals typified by beryllium, aluminum, and magnesium; and the so-called refractory metals including titanium, zirconium, molybdenum, tungsten, columbium, and tantalum.

After outlining possible uses for these now unplateable metals, Dr. Brenner went on to discuss why they cannot be deposited from aqueous solutions. The reasons in general fall into two classes: their potentials are too high and therefore cannot be reached in solutions containing ionizable hydrogen or, as in the case of the refractory metals, no simple ions exist and there are therefore no simple equilibria at the cathode surface.

In the main body of his talk, Dr. Brenner discussed the two principal types of nonaqueous baths, namely fused-salt baths and organic solvents. These two types shade off into each other as in the case where low-melting organic salts are used which could be classified as either fused salts or organic solvents. The speaker discussed in particular the plating of molybdenum from fused salts and the plating of aluminum from organic solvents.

The meeting was followed by an unusually lively discussion in which many in the audience took part.

F. A. Lowenheim, *Secretary*

Niagara Falls Section

The Niagara Falls Section held a meeting on January 14, 1953, at the Red Coach Inn, Niagara Falls, New York. Twenty-three members and guests were present for the dinner with thirty-five at the meeting following. After a brief business meeting, Dr. J. C. Warner, National President of The Electrochemical Society and President of the Carnegie Institute of Technology, addressed the section on the subject of "History of Theories of Electrolytes."

Dr. Warner traced the development of theories of electrolytes from the pioneer work of Galvani and Volta, the experimental researches of Davy and Faraday, and the early ideas of Grotthuss and Clausius. Grotthuss proposed a theory of conductance which made no assumption of free ions in solution, and it seems likely that Faraday did not assume ionization in the absence of an applied field. Clausius proposed a statistical theory of ionic dissociation which would yield only a very small ionic concentration in the absence of an applied field.

Following the classical experimental research of Hittorf and Kohlrausch, Dr. Warner emphasized the little known work of Valson in 1870, who from his work on surface tension and refractive index came close to anticipating the basic postulate of Arrhenius some 15 years later. Following the work of Van't Hoff and Rauolt on the colligative properties of solutions came the

J. C. Warner

famous theory of Arrhenius on electrolytic dissociation. Here, Dr. Warner entered a plea that in present day teaching the modern theories of electrolytes should be emphasized with the theory of Arrhenius regarded in its proper though brilliant historical perspective.

The defects of the Arrhenius theory became increasingly apparent and suggestions of complete dissociation were made by Noyes, Bjerrum, Van Laar, etc. Ghosh's theory was contrary to the observed relations of conductance and Milner's theory was so complex mathematically that it was largely ignored, although since regarded as essentially sound.

Dr. Warner then discussed the basic ideas of the Debye-Hückel theory of the thermodynamic properties of electrolytic solutions, the Debye-Hückel-Onsager theory of conductance, and the evidence that has now accumulated to support a theory of complete dissociation.

Milton Janes, *Secretary-Treasurer*

Philadelphia Section

The Philadelphia Section held its second meeting of the season on January 7 in the Harrison Laboratory of Chemistry at the University of Pennsylvania. An unusually large group of 80 or so members and guests heard an interesting presentation of the theoretical and practical aspects of ion exchange membranes given by Dr. George W. Bodamer and Dr. Alvin C. Winger, both of Rohm and Haas Company, Philadelphia.

Those members and guests who attended an enjoyable dinner prior to the meeting had the opportunity of meeting the speakers informally. Chairman John F. Gall presented Dr. Bodamer and Dr. Winger to the meeting group, both of whom are well known to the Philadelphia Section and active in its affairs.

Dr. Winger presented, theoretically, the properties of ion exchange membranes. Expressions for the permselectivity, the concentration dependence of permselectivity, and the concentration and temperature dependence of membrane conductivity were considered.

Dr. Bodamer then discussed several uses of ion exchange membranes, including the preparation of salt-free caustic, the liberation of organic acids from their metal salts and of amines from their mineral acid salts, treatment of waste materials, and the de-salting of sea and brackish waters. The speakers illustrated their talks with small laboratory models of various cells and, after their formal presentations, answered questions from the audience. The meeting was closed by a rising vote of thanks to the speakers.

E. L. Eckfeldt, *Secretary*

Pittsburgh Section

The Pittsburgh Section, at its meeting on December 1, heard an unusually interesting address by Earl A. Gulbransen, Westinghouse Research Laboratories, Pittsburgh, on "Corrosion Research in Europe."

Dr. Gulbransen had recently returned from a six-month visit to a number of laboratories in eight European countries. His talk included a detailed discussion of the following groups:

1. G. I. Finch's group in London on the Electro-Optical Study of Corrosion.
2. J. Benard's group in Paris on the Nucleation Process in Low Pressure Oxidation of Iron.
3. G. Chaudron's group in Paris on the Transformation Research in the Iron Oxide.
4. W. Feitknecht's group in Bern on

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the Structure of the Corrosion Products of a Number of Metals.

Comments also were made concerning the work of Vernon and Evans in England and Pourbaix in Belgium.

A particularly interesting discussion period followed Dr. Gulbransen's talk during which it was decided to consider the possibilities of conducting a panel discussion concerning anodic coatings of metals.

R. D. WILLIAMS, *Secretary-Treasurer*

India Section

At the annual meeting of the Indian Institute of Metals, held on February 27 at Bangalore, a symposium on "Metallurgy in Electro-Process Industries" was held under the joint auspices of the Indian Institute of Metals and the India Section of The Electrochemical Society.

A symposium on "Electrolytic Alkali Chlorine" was held at the Indian Institute of Science, Bangalore, on February 26, 27, and 28, under the auspices of the India Section.

The two companies listed below have recently become Patrons of the India Section:

1. Kamani Metals and Alloys, Ltd., Bombay.
2. Tata Chemicals Ltd., Bombay.

The latest issue of the *Bulletin of the India Section*, Volume 2, Number 1, was published in January, 1953.

J. BALACHANDRA, *Secretary-Treasurer*

PERSONALS

WALLACE DRUMHILLER, formerly research assistant at the University of New Mexico, Albuquerque, is now employed by the University of California at the Los Alamos Scientific Laboratory, Los Alamos, N. Mex.

SAMUEL H. DREISBACH has accepted a position as research electrochemist at Kaiser Aluminum & Chemical Corporation, Spokane, Wash. Mr. Dreisbach has been at the University of Michigan, Ann Arbor, Mich.

ALLEN S. BRUMM has left Precision Castings Company, Finishing Division, of Kalamazoo, Mich., to accept a posision as plating engineer with Kuehne Manufacturing Company, Matton, Ill.

WILLIAM E. KUHN has joined the Carborundum Metals Company, Niagara Falls, N. Y. Mr. Kuhn was previously with the Titanium Alloy Manufacturing Division of National Lead Company, Niagara Falls.

GUSTAF SODERBERG, consulting engineer and lecturer at Chalmers Institute of Technology, Gothenberg, Sweden, is now residing at Saevedalen, Sweden.

DONALD R. MARTIN, formerly with the Naval Research Laboratory, Washington, D. C., has joined the Mathieson Chemical Corporation, Niagara Falls, N. Y.

ALLEN G. GRAY has been appointed Technical Editor of *Steel* magazine, Cleveland, Ohio. Mr. Gray had been consulting editor on *Steel* for the past several years. He was most recently connected with the Du Pont Atomic Energy Division of Knolls Atomic Power Laboratory, Schenectady, N. Y.

JAMES B. GODSCHALK is now employed at Fox Products Company, Philadelphia. Mr. Godschalk had been associated with Leeds & Northrup Company, Philadelphia.

CHESTER G. BORLET, formerly with United Chromium, Inc., Los Angeles, Calif., has joined the McGean Chemical Company, Detroit, Mich.

PHILIP B. BROWN has resigned from the A S & R, Parral. Chihuahua, Mexico, and has formed his own mining company in the same city. He plans to work with connections in the U. S.

GERALD G. HATCH, formerly with Armour Research Foundation, Chicago, Ill., has been appointed Director of Research, Quebec Iron & Titanium Corporation, Sorel, Quebec.

EDWARD L. MACK

Edward L. Mack, of Flushing, New York, died on November 6, 1952 at the age of 62.

Dr. Mack was born in Vergennes, Vermont, and was educated at Union College and Cornell University, New York, where he received the B.S. and Ph.D. degrees, respectively. He was connected with the Bureau of Mines in Ithaca, and later with the Reynolds Research Corporation and the Graphic Arts Research Corporation. His interests were in the fields of metallic foils, textile laminating, and alloy steels.

He was a longtime member of The Electrochemical Society, having joined in 1915.

LELAND A. WOOTEN

Leland A. Wooten, Director of Chemical Physics, Bell Telephone Laboratories, Murray Hill, New Jersey, died on December 29, of a heart attack.

Dr. Wooten was born in Statesville, North Carolina, in 1900. He received his B.S. degree from Davidson College and the Ph.D. degree from Columbia University. His early years were devoted to teaching and in 1928 he joined the technical staff of Bell Laboratories. In 1947 he was placed in charge of Analytical Chemistry and Chemical Electronics Research and Engineering and last year was made director of Chemical Physics. His interests were in analytical and physical chemistry, and chemistry of electron tube materials, semiconductors and transistor materials.

He became a member of The Electrochemical Society in 1944.

NEW MEMBERS

In January 1953, the following were elected to membership in The Electrochemical Society:

Active Members

ROBERT T. BANISTER, Thompson Products, Inc., 23555 Euclid Ave., Cleveland, Ohio (Electrodeposition and Theoretical Electrochemistry)

STEVE EISNER, Dept. 487, Central Engineering, Chrysler Corporation, Highland Pk., Mich. (Electrodeposition)

ANDREW GEMANT, The Detroit Edison Company, 2000 Second Ave., Detroit, Mich. (Electric Insulation)

STEPHEN HEBEL, George Miller & Company, Ltd., mailing add: 2 Alexandra Court, 60/1 Chowringhee Rd., Calcutta, India (Corrosion and Electrodeposition)

ISIDOR S. HIRSCHHORN, New Process Metals, Inc., mailing add: 56 Greenwood Ave., West Orange, N. J. (Industrial Electrolytic)

FRANCOIS J. OLMER, Armour Research Foundation, Chicago, Ill. (Battery, Electrodeposition, Industrial Electrolytic, and Theoretical Electrochemistry)

JOHN PARINA, JR., American Society for Metals, mailing add: 1441 Mail Ave., Lakewood, Ohio (Corrosion, Electrodeposition, and Industrial Electrolytic)

FERNAND F. C. PORTAIL, Compagnie Industrielle des Piles Electriques, 94 rue Charles Laffitte, Neuilly (Seine) France (Battery)

RALPH M. POTTER, General Electric Company, Lamp Development Laboratory, Nela Park, Cleveland, Ohio (Electronics and Theoretical Electrochemistry)

V. R. RAMANATHAN, The Central Electrochemical Research Institute, Alagappa College, P.O. Karaikudi, S. India (Electric Insulation and Theoretical Electrochemistry)

THOMAS RAPHAEL, Dewey and Almy Chemical Co., mailing add: 24 Tufts Rd., Winchester, Mass. (Battery)

WALTER J. SAKOWSKI, Mathieson Chemical Corporation, mailing add: Balmer Rd., Youngstown, N. Y. (Industrial Electrolytic)

RICHARD H. SINGLETON, National Research Corporation, mailing add: 379 Woburn St., Lexington, Mass. (Corrosion, Electrodeposition, Electrothermic, and Industrial Electrolytic)

RAMASWAMY THYAGARAJAN, The Indian Aluminum Company, Ltd., Alupuram Alwaye, S. India (Corrosion, Electrothermic, Industrial Electrolytic, and Theoretical Electrochemistry)

THOMAS H. VAUGHN, Library, Research & Development, Wyandotte Chemicals Corporation, Wyandotte, Mich.

Associate Members

HARRY C. MANDELL, JR., University of Pennsylvania, mailing add: 601 E. Anchor St., Philadelphia, Pa. (Electrodeposition, Electronics, Electro-Organic, and Theoretical Electrochemistry)

IVOR L. SIMMONS, Metal and Thermit Corporation, mailing add: % Rosenthal, Apt. 210, 81-10 135th St., Kew Gardens, L. I., N. Y. (Electrodeposition and Theoretical Electrochemistry)

Reinstatement

Student Associate Member

BORIS LEVY, 2464 East 21st St., Brooklyn, N. Y.

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BOOK REVIEWS

AN INTERNATIONAL BIBLIOGRAPHY ON ATOMIC ENERGY, Vol. 2, Scientific Aspects, Supplement No. 1 by Atomic Energy Section, Department of Security Council Affairs, United Nations, New York. Distributed by Columbia University Press, New York, 1952. $3.50.

This is a supplemental bibliography of 8,231 references to papers published in 1949 and 1950 in the general fields of fundamental nuclear science, the physics and engineering of nuclear reactions, the biological and medical effects of high energy radiations, isotopes in biology and medicine, and application of radioactive tracers in nonbiological sciences and technology. There is an author index and a list of journals from which the references are given.

R. M. BURNS

THEORY OF ELECTRIC POLARISATION by C. J. F. Böttcher. Published by Elsevier Publishing Company, Houston, Texas, 1952. 492 plus xiii pages, $10.00.

Professor Böttcher's new book is an addition to the literature in dielectric theory which will be welcomed by the student as a comprehensive text and by the worker in the field as a reference book. Although the author, in his preface, calls it an introduction to the subject for advanced students, it appears to this reviewer that the student should have some acquaintance with the subject before attempting to read this book.

The treatment from basic electrostatics to the more advanced considerations of dipoles in liquids and solids is classical throughout. It is highly mathematical and although a number of appendices are included on vectors,

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tensors, and other mathematical apparatus, it is largely assumed that the reader has the necessary background to handle the material. The derivations are given in detail, and a good physical picture is presented, supplemented by numerical calculations. A large number of interesting electrostatic problems are considered and the book possesses the unity and rigor necessary for a comprehensive theoretical presentation.

The experimental worker will especially appreciate Chapter IX which considers the determination of dipole moments from measurements in gases and liquids, and Chapter X which considers dielectric loss; in both chapters a correlation with molecular structure is presented. An excellent review and comparison of the methods of extrapolating data obtained on solutions is given; pure dipole liquids are also discussed. The phenomenon of dielectric relaxation is treated together with dielectric loss, and the theory of rate processes is introduced in this connection. Several tabulations of experimental data are scattered throughout these sections but a separate chemical name index is included to aid in finding information for any particular compound.

Special topics, such as piezoelectricity and ferroelectricity, are treated briefly. Multiphase systems are considered only for the special case of crystalline powders; the more general Maxwell-Wagner effect is merely mentioned in passing, and nothing is said of interfacial polarization.

Professor Böttcher's notation is slightly different from that common in this country, and his use of electrostatic rather than m.k.s. units may disturb some readers, but these are carefully explained and consistently used and should cause no trouble. The book is well indexed, and well annotated with literature references, which seem to be quite up to date.

D. Edelson

Exhaust Hoods, 2nd ed., by J. M. Dalla Valle. Published by The Industrial Press, New York, 1952. 146 plus vi pages, $3.50.

The book presents the theories for the design of exhaust hoods, a special subject in the general field of ventilation, in a readily understood manner with practical examples. The phases related to legal and health requirements are pertinent and the book is useful reference material for laboratory and industrial installations.

J. G. Motley

EMPLOYMENT SITUATION

LABORATORY THERMOMETERS. Catalogue describes over 200 different thermometers from −330°F to +760°F, includes prices, and introduces two recently developed models. Brooklyn Thermometer Co. P-111

VOLTAGE REGULATED POWER SUPPLY. Illustrated leaflet describes a new standard voltage regulated power supply featuring one regulated B supply and one unregulated filament. Excellent regulation, low ripple content, and low output impedance are characteristics. Kepco Laboratories, Inc. P-112

TESTING METHODS. Eighty different methods for testing, inspecting, and analyzing some ninety different types of products are listed in new folder now available. Shows scope of services available for the quality control of many products, and the facilities for performing these services in the field or in the laboratory. American Standards Testing Bureau, Inc. P-113

HIGH-TEMPERATURE LUBRICANT. How 'dag' colloidal graphite has been used successfully to lubricate kiln cars at 450°F, oven conveyors up to 1200°F, and forging dies at over 2000°F, is described in a new, illustrated bulletin. Acheson Colloids Co. P-114

PLASTIC PIPE. A 16-page brochure on plastic pipe contains all pertinent information on company's four types: Flexible, Semi-Rigid, Rigid High Impact, and Rigid Polyvinyl Chloride Pipe. Detailed tables give chemical and physical characteristics of each type. Triangle Conduit and Cable Co. Inc., Plastic Products Division. P-115

MASS SPECTROMETER. 20-Page brochure, with diagrams and photographs, gives detailed description of design, quality of workmanship, and performance features of Model 21-103A Mass Spectrometer. An integrated assembly of precision units, it is composed of three sections, interconnected to form a complete, self-contained instrument. Consolidated Engineering Corp. P-116

YARDNEY SILVERCEL.* Known as the smallest and lightest storage battery in the world, the Silvercel has extremely high capacity per unit weight and volume. Full description of physical and electrical characteristics given in illustrated folder. Yardney Electric Corp. P-117

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CONTROL-CENTER BOOKLET. New 31-page application booklet on control centers stresses the case for centralizing all controls of an entire system in one group of enclosures. Also discusses characteristics that make for flexibility of application, ease of servicing, and safety of operating personnel. Westinghouse Electric Corp. P-118

INDUSTRIAL WIRE CLOTH . . . and special metal fabrications. Folder illustrates and describes various types of wire cloth, available in any metal or alloy to meet individual specifications. Sizes from 20 to 250 mesh up to 4 in. openings. Also screens, filter leaves, baskets, trays, etc., for all types of industrial processes. Cambridge Wire Cloth Co. P-119

OXIDE REMOVAL PROCESS. Bulletin announces a new alkaline procedure for the removal of cuprous and cupric oxides from copper and copper alloys. Also information on Ebonol "C" process for blackening and coloring of copper and copper alloys. Enthone, Inc. P-120

LABORATORY INSTRUMENTS. Now available is the 1465-page, 1953 catalogue of scientific laboratory instruments, apparatus, supplies, and chemicals. Distributed on request to qualified laboratory persons. E. H. Sargent & Co. P-121

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RECENT PATENTS

Selected for electrochemists by Fred W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

October 21, 1952

Wood, W., and Bowen, C. E., 2,614,977, Mercury Cathode Electrolytic Cell

Brandt, G. E., 2,615,061, Battery Plate

Craig, P. H., 2,615,062, Storage Battery Cap with Gas Recombining Means

Claessen, W. H. L., 2,615,140, Electric Discharge Tube Containing an Alkaline Metal

October 28, 1952

Ellis, G. B., Application 111,751, RM Cell Structure

Baldwin, J. H., Application 215,565, Prevention of Short Circuiting of Leakage Currents

Maybach, G. E., 2,615,337, Battery Liquid Level Indicator

Deuth, A. F., 2,615,777, Electrolytic Recorder with Self-Renewing Electrode

Minnick, L. J., and Presgrave, C.,

ADVERTISERS' INDEX

Bell Telephone Laboratories.. 52C
Dow Chemical Company..... 54C
Enthone, Inc. Cover 4
General Chemical Corporation 56C
Great Lakes Carbon Corporation..... Cover 2
Lea Manufacturing Company..... Cover 3
Lindberg Engineering Company.....71C, 74C
Merck & Company..... 66C
Raytheon Manufacturing Company..... 75C
E. H. Sargent & Company.... 65C
Todd Scientific Company..... 55C
Western Electrochemical Company..... 73C

2,615,838, Electrolytic Process of Producing Alkali and Alkaline Earth Metals

Chester, A. E., 2,615,836, Method of Bonding Vitreous Enamels

Liger, A. W., 2,615,837, Electroplating Bath and Process

Willier, H. O., 2,615,839, Recovery of Precious Metals from Photographic Baths

Chapman, A. A. G., 2,615,840, Electrolytic Method to Remove Rust

Thorp, C. E., and Panula, G., 2,615,841, Ozone Generation

Wells, R. S., 2,615,848, Method of Producing Magnesium Arsenate Phosphor Activated by Manganese

Markoski, J. A., 2,615,849, Infrared Quenchable Zinc Sulfide Phosphors

McKeag, A. H., 2,615,850, Manganese Activated Zinc Lithium Silicate Phosphor

Moulton, J. D., and Enters, R. F., 2,615,930, Method of Making Positive Electrodes for Battery Cells

Hatfield, M. R., 2,615,931, Heavy Duty Gas Depolarized Dry Battery

Marko, A., and Kordesch, K., 2,615,932, Process for Manufacturing Porous Carbon Electrodes

Carlson, D. J., and Decot, H. T., 2,615,933, Battery Heating System

Lark-Horovitz, K., and Whaley, R. M., 2,615,966, Alloys and Rectifiers Made Thereof

Glasener, C. R., Willard, A. R., and Weiler, C. R., 2,616,015, Machine for Welding Battery Plates

November 4, 1952

Bügel, R. D., 2,616,799, Electrolytic Capacitor

Brennan, J. B., 2,616,165, Electrode for Electrolytic Devices and Methods of Making Same

Levi, R., 2,616,840, Rhenium Plating

Stareck, J. E., 2,616,841, Process of Reducing Cuprous Oxide Coatings to Produce Patterns or Designs, and Baths for Use in the Process

Sheer, C., and Korman, S., 2,616,842, Arc Process for the Production of Fume

Sheer, C., and Korman, S., 2,616,843, Arc Process for the Reduction of Metals

Klumb, G. H., 2,616,844, Anode Construction for Use in Cathodic Protection for Water Softeners and Filters

Kreml, J. F., 2,616,845, Electrolytic Polishing Apparatus

Kullgren, B. C. J., 2,616,937, Alkaline Accumulator

Brandt, G. E., 2,616,938, Electrode for Galvanic Cells

Fischbach, A., 2,616,939, Sponge Cadmium Electrode and Method of Making the Same

Reid, R. W., 2,616,940, Primary Cell

Lasko, G. A., 2,616,941, Indicating Apparatus

Cade, P. J., 2,616,949, Conductivity Cell Test Element

Terpstra, J., 2,616,950, Apparatus for Continuously Determining the Electrical Conductivity of a Liquid

Booe, J. M., 2,616,953, Electrolytic Condenser

November 11, 1952

Sheer, C., and Korman, S., 2,617,761, Arc Process for the Selective Recovery of Metals

Basilewsky, A., 2,617,762, Anode Device

Fischer, K. A., 2,617,763, Apparatus for Electrically Filtering Paraffins

Nagy, R., and Wollentin, R. W., 2,617,773, Lead Activated Calcium Tungstate Phosphor

November 18, 1952

Horvitz, G. J., 2,618,592, Electrolytic Process for Recovering By-Products From Industrial Waste Liquors

Rossel, R. M., 2,618,593, Apparatus for Cleaning, Sterilizing, and Drying Dental Drill Burrs

Van der Pyl, E., 2,618,671, Tunnel Kiln

Cizmadia, L., and Maloit, R. J., 2,618,672, Apparatus for Measuring the Temperature of a Moving Surface

Shannon, J. K., and Schmit, R. R., 2,618,673, Cover for Batteries

Lallmang, H. C., 2,618,675, Battery Terminal Clamp

November 25, 1952

Glasstone, S., 2,619,437, Primary Cells

Zapponi, P. P., 2,619,454, Method of Manufacturing a Magnetic Recording Medium by Electrodeposition

Harris, W. W., and Brown, W., 2,619,455, Galvanic Anode

EMPLOYMENT SITUATIONS

Please address replies to box shown, c/o The Electrochemical Society, Inc., 235 W. 102nd St., New York 25, N. Y.

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ELECTROCHEMIST. Twelve years experience in electrowinning, plating process development, corrosion problems, primary battery development, and metallurgy. Patents and publications. Good speaker and technical writer. Age 33. Desires research and development work, preferably in South or Southwest. Other locations considered. *Reply to Box 352*

Positions Available

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CORROSION CHEMIST. Industrial laboratory performing metallurgical research requires man to initiate and carry out fundamental inquiries pertinent to mechanisms of corrosion of metals in various corroding media. Develop testing techniques for investigating electrochemical phenomena which may be involved in the corrosion of various metals in different environments. Ultimate objective of research is the origination of new alloys with superior corrosion resistance and the development of treatments that will enhance the corrosion resistance of present materials. Please send outline of qualifications, personal background, and educational summary. *Reply to Box A-244.*

CHEMICAL ENGINEER to act as production consultant for chemical plant in Eastern Ohio. Experience with commercial roasting, leaching, washing, filtering, and electrolytic equipment desirable. Salary commensurate with background and experience. Opportunity with expanding company. Send complete resumé and salary information. Interviews arranged. *Reply to Box A-245.*

Editorial

Educate the Gifted

IN HIS thoughtful lectures upon the philosophy and curriculum of secondary school education, now published under the title "Education and Liberty," James Bryant Conant points out that the foremost shortcoming of the public schools "is their failure to be concerned with the intellectually able youth." In further discussion of the situation, he says that "my continuing plea to high-school superintendents, principals, and teachers is that they must be far more effective in identifying the academically able youth and be more concerned with preparing him for a university education."

It is particularly timely that this problem of identifying and training the gifted youth of our country be widely recognized. With the prospect of greatly increased secondary school enrollments within the next few years—there are at present about 50 per cent more children under 8 years of age than there are in the age group 10 to 18—and, in view of the tremendously expanding needs for chemists and physicists it is important that plans, policies, and facilities be made now to meet the situation. It is surely in the national interest to bring about a reversal in the present trend of diminishing enrollment in science and engineering. The raw material will become available shortly. How shall the talented be recognized and nurtured? For the vast majority of young people who will want a secondary school education, the comprehensive high schools in the larger communities, expanded perhaps in numbers, may meet the requirements by offering diversified courses to meet the varied interests. Within this structure, it may be possible to develop the means for screening and segregating those of high intellectual potential. Such individuals will deserve to be taught by the best teachers in schools equipped with the most modern facilities. In smaller secondary schools, detection of unusual talent should be urged upon teachers as their most important responsibility.

Elsewhere in this issue, it is suggested that the principal barrier to greater student enrollment in the science courses is indifferent teaching. Teachers with little knowledge and no professional interest in chemistry, and there are many such in our secondary schools, cannot be expected to fire their charges with enthusiasm for chemical careers. What is it like to be a chemist? What are the opportunities? What are the satisfactions of a scientist or an engineer? Only the gifted teacher can convey inspirational answers to such questions. Not until parents and public-spirited citizens demand better teachers and are willing to pay for them will this situation be much improved. It is high time that a beginning be made! —RMB

*A **Transistor** of point-contact type. Two hair-thin wires control current flow in germanium metal.*

It's helping to win the Battle of the Watts

*Laboratories engineer examines **Transistor** oscillator. It is used in Englewood, New Jersey, where 10,000 subscribers can personally dial distant cities. **Transistors** generate the signals which carry the dialed numbers to other towns and cities. Other uses are in prospect.*

When you keep down the power needed to send voices by telephone you keep down the special equipment needed to supply that power. A great new power saver for telephony is the ***Transistor***, invented at Bell Telephone Laboratories, and now entering telephone service for the first time.

Tiny, simple and rugged, the ***Transistor*** can do many of the things the vacuum tube can do, but it is not a vacuum tube. It works on an entirely new principle and uses much less power than even the smallest tubes. This will mean smaller and cheaper power equipment, and the use of ***Transistors*** at many points in the telephone system where other equipment has not been able to do the job as economically.

It's another example of how Bell Telephone Laboratories makes basic discoveries, then applies them to improve telephone service while helping to keep its cost down.

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Feature Section

The Electric Furnace as a Producer of Elemental Phosphorus

Harry A. Curtis[1]

Elemental phosphorus was first isolated by Brandt in 1669 and remained an interesting laboratory curiosity for more than two centuries thereafter. Brandt used the residue from evaporated urine as his source, but it was presently discovered that bones, silica sand, and charcoal when heated together would yield phosphorus, and still later natural rock phosphate was substituted for bones in the process. The temperature required was relatively high, and the molten calcium silicate was corrosive. The worst handicap encountered was that the heat necessary to keep the reactants at the required temperature and to furnish the heat for the endothermic reaction involved had to be transmitted through the walls of a crucible. Eventually it was found that some of the difficulties could be avoided by first extracting the phosphate with sulfuric acid, then evaporating the resultant phosphoric acid as much as possible, and finally reducing the acid with charcoal. Even then the corrosion problem was difficult because, again, the heat required had to be transmitted through the crucible walls.

When the electric arc furnace was first invented, it was obvious that such a furnace offered great advantages in smelting rock phosphate, but for a long time thereafter there was no economical way of generating electric energy. It was only in the closing decades of the nineteenth century that mechanically driven electric generators were at last perfected. Hydroelectric generators furnished the final link in the chain of developments that brought electric furnaces of all sorts into general use. It was no accident that our earliest electroprocess industries grew up around the hydroelectric power plants at Niagara Falls in the early decades of the current century.

At first the production of elemental phosphorus in the Niagara Falls region expanded but slowly, for the industrial demand for this material remained small as compared with the growing demand for such products as graphite, silicon carbide, and calcium carbide. A few small phosphate-smelting furnaces were built in this country elsewhere than near Niagara Falls, but the quantity of elemental phosphorus produced in the United States remained relatively small and the urgent demand for this material during World War I could not be met.

Shortly after the close of World War I, the Federal Phosphorus Company (Swann) began the production of phosphorus in a small electric furnace at Anniston, Alabama. In 1933–34 the Tennessee Valley Authority constructed two relatively large electric furnaces (6000–8000 kw) and used the phosphorus produced to manufacture phosphatic fertilizers. Shortly thereafter came a rapid expansion of phosphorus production in the Tennessee Valley region by privately owned corporations utilizing the relatively cheap hydroelectric energy from the TVA power system. The Monsanto Chemical Company installed furnaces at its phosphate mines near Columbia, Tennessee; the Victor Chemical Company, which had been operating a small blast furnace for phosphorus production near Nashville, Tennessee, abandoned the blast furnace process and set up electric furnaces near Mount Pleasant, Tennessee, modeled after the TVA furnaces at Wilson Dam, Alabama. All three of the phosphorus-producing plants mentioned above have been greatly expanded since the initial installations in the 1930's. The most recent addition to the plants in Tennessee is that of the Shea Chemical Company near Columbia, Tennessee, but during the past decade there have been several phosphorus-producing plants built elsewhere, notably in Florida, South Carolina, Idaho, and Montana. Table I lists present installations in the United States and the capacities of the several plants.

TABLE I. *Phosphorus-producing plants in the United States**

Company	Plant location	Production capacity (Tons/yr)
TVA	Wilson Dam, Ala.	36,000
Monsanto Chemical Co.	Columbia, Tenn. Soda Springs, Idaho	110,000
Victor Chemical Co.	Mount Pleasant, Tenn.	35,000
Victor Chemical Co.	Silver Bow, Mont.	28,000
Victor Chemical Co.	Tarpon Springs, Fla.	10,000
Westvaco Chemical Co.	Pocatello, Idaho	41,000
Virginia-Carolina Chemical Co.	Charleston, S. C.	9,000
Virginia-Carolina Chemical Co.	Nichols, Fla.	5,000
American Agricultural Chemical Co.	South Amboy, N. J.	3,000
American Agricultural Chemical Co.	Pierce, Fla.	5,000
Oldbury Electro-Chemical Co.	Niagara Falls, N. Y.	8,000
Shea Chemical Co.	Columbia, Tenn.	20,000
		310,000

* *Chemical Week*, February 7, 1953.

This great expansion in phosphorus production in the past two decades has not been induced by the rapidly growing demand for phosphatic fertilizers, and to date very little of the phosphorus produced, aside from the TVA output, has gone into fertilizer production. The initial urge for expansion of production came when it was demonstrated that concentrated phosphoric acid of purity required for food products and for most industrial uses could be prepared more economically by the electric furnace method than by the older process using sulfuric acid and rock phosphate. The many industrial uses for high purity phosphoric acid were meanwhile expanding rapidly and, within the past decade, this

[1] Director, Tennessee Valley Authority, Knoxville, Tennessee.

market has been augmented by the development of various detergents containing phosphorus compounds.

One may reasonably guess that the next decade will not witness such a rapid expansion of the electrothermal production of phosphorus as has come about from 1935 to date unless it is found that electric furnace phosphorus can be used to produce concentrated phosphatic fertilizers in competition with the older sulfuric acid method or the newer nitric-sulfuric acid method. Up to the present the industrial demand for high purity phosphorus chemicals has more than kept pace with the increased production of phosphorus by the electric furnace method. The result has been that up to the present the price level of elemental phosphorus has been far above its cost of production in the large modern installations. There is no evidence of price competition among the large producers as yet. Evidence of this situation is the fact that identical prices have recently been quoted for phosphorus delivered from nearby and far distant manufacturing plants regardless of a freight differential of more than $60 per ton. It seems very improbable that production costs could vary by any such amount. This situation is by no means unique in the current market for items other than phosphorus, but such a situation is not likely to continue indefinitely and it appears that, sooner or later, the present phosphorus producers will begin exploring seriously the possibility of capturing some of the fertilizer market from which the current price of phosphorus shuts them out. There are probably locations in the United States where the electric furnace method may indeed compete successfully with the other methods of producing phosphatic fertilizers.

* * *

Let us now turn from this brief historical and economic discussion of the phosphorus-producing industry to a technical discussion of the phosphate-smelting electric furnace.[2]

Chemical Reactions and Heat Distribution in a Phosphate-Smelting Electric Furnace

In a furnace of this sort, phosphorus is liberated from rock phosphate by the reaction of a reducing agent, such as coke. This reaction occurs only at high temperatures and the function of the electric energy liberated in the furnace is solely to supply the necessary heat. Silica is added to flux the furnace charge and thereby facilitate the reaction through the formation of a molten magma; very little reaction between the coke and rock phosphate occurs prior to the formation of a molten magma in the furnace. The molten slag remaining after the phosphorus has been volatilized is tapped from the furnace periodically.

The metallic iron formed in the furnace through the reduction of iron compounds in the charge absorbs phosphorus to form a metallic material known as ferrophosphorus. This sinks to the floor of the furnace and is withdrawn from time to time.

The offgases, carrying about 9 per cent of elemental phosphorus and nearly 90 per cent of carbon monoxide, are cleaned and then cooled so as to condense the phosphorus to the liquid form, in which it is removed from the gas stream.

Numerous reactions other than the reduction of the rock phosphate and the formation of a silicate slag take place in the furnace. Iron compounds are almost completely reduced; carbonates are decomposed and most of the resultant carbon dioxide is reduced to the monoxide; alumina becomes a component of the slag; and other impurities are wholly or partially reduced. The metallic iron formed dissolves elemental phosphorus to form a ferrophosphorus containing from about 17 to 28 per cent phosphorus, and this alloy in turn dissolves any metallic titanium, manganese, silicon, or other metals formed in the furnace. All nonreduced, nonvolatilized compounds are picked up by the slag. The furnace offgases consist chiefly of carbon monoxide and phosphorus vapor but small proportions of water vapor, carbon dioxide, hydrocarbons, potassium compounds, fluorine compounds, etc., are present.

In view of the fact that so many things occur in the furnace, it is obvious that no very exact statement can be made regarding the distribution of the electric energy liberated in the furnace. Most of the chemical reactions that occur, along with processes of fusion and vaporization, are endothermic and a considerable part of the total electric energy delivered is necessary to meet these requirements. The molten slag and ferrophosphorus tapped from the furnace carry away a considerable proportion of the energy, as do the offgases. Also, energy is lost as heat from the surfaces of the furnace and electrodes. As an approximation, it may be assumed that of the total electric energy delivered to the electrodes, the distribution in Table II will be found in a large, well-designed furnace.

TABLE II. *Heat distribution in electric furnace*

Total net heat for reactions	51%
Sensible heat in slag	29
Sensible heat in ferrophos	1
Sensible heat in volatiles	5
Heat loss from surfaces of the furnace and electrodes	9
Heat not accounted for	5
	100%

Electric Energy Required per Ton of Phosphorus Volatilized and per Ton of Phosphorus Recovered

In general, an electric furnace will volatilize most of the phosphorus from any properly proportioned mixture of rock phosphate, silica, and coke, regardless of the grade of rock phosphate used. However, the lower the grade of the rock phosphate, the greater the proportion of slag formed per unit of phosphorus volatilized and, therefore, the greater the electric energy required per unit of phosphorus produced. Even this simple statement must be hedged, however, for it makes a difference what impurities are present in the rock. The electric furnace doesn't operate smoothly if the weight ratio of silica (SiO_2) to lime (CaO) in the slag is below about 0.7, and with most charges the furnace works best if this ratio is kept near 0.8. A rock phosphate might carry, as an impurity, enough silica to meet this silica to lime ratio; in another rock phosphate supply of the same grade so far as phosphate content was concerned, it might be necessary to add silica to the furnace charge in order to meet the ratio requirement, particularly if the impurity present were largely calcium carbonate. In the latter case there would be more slag produced per ton of phosphorus volatilized than in the former case, and therefore more electric energy required even though the grade of the two rock phosphate supplies were the same.

Because of the situation outlined above, it is obvious that

[2] A more detailed discussion of such a furnace will be found in TVA's *Chemical Engineering Bulletin No. 1*, from which a considerable part of the remainder of the present article is drawn.

the P_2O_5 content of the mixture of rock phosphate and silica fed to the furnace is a more significant figure than is merely a figure indicating the grade of the rock phosphate alone. It follows that one must know the approximate average composition of the rock phosphate supply available. With this information at hand, the silica to be added can then be calculated and the data obtained in the operation of existing furnaces used to arrive at an estimate of the energy required per ton of phosphorus volatilized.

Not all of the phosphorus contained in the furnace charge is volatilized. Some inevitably goes into the slag; under good operating conditions it may be assumed that the slag will carry about 1 per cent of P_2O_5 equivalent, and, inasmuch as the lower the P_2O_5 content of the rock phosphate-silica mixture fed to the furnace the more slag will be formed per unit of phosphorus volatilized, it follows that the proportion of the total phosphorus lost in the slag will be inversely proportional to the P_2O_5 content of the rock phosphate-silica mixture in the furnace charge. Not all of the nonvolatilized phosphorus goes into the slag; the ferrophosphorus accounts for some. The phosphorus content of the ferrophosphorus will vary with conditions of furnace operation and will ordinarily be in the range of 17 to 28 per cent; an average of 23 per cent may reasonably be assumed. The quantity of ferrophosphorus formed per unit of P_2O_5 equivalent in the rock phosphate-silica charged will, of course, vary directly with the iron content of the charge, and, since nearly all the iron in the furnace charge is present in the rock phosphate, the proportion of ferrophosphorus that will be formed may be estimated rather closely from the chemical analysis of the rock phosphate used.

As an illustration of how the estimates suggested above would be made, the following specific example is cited, using as a basis the raw materials indicated in Table III.

Assume that a ton of phosphate nodules is charged. The coke theoretically required to reduce the P_2O_5 and the Fe_2O_3 in the nodules would be 299 lb, considering that the coke carries 82.6 per cent carbon and neglecting the iron content of the coke. Actually, it is economical in furnace operation to use a little larger proportion of coke than thus calculated. The excess desirable must eventually be determined on the basis of furnace-operation data, but for the present purpose an excess of 3 per cent may be assumed, giving a total of 308 lb of coke.

The ton of nodules and the 308 lb of coke would contain 503 lb of SiO_2. The SiO_2 required by the CaO in the ton of nodules (neglecting the CaO in the silica pebble) would be 624 lb if the weight ratio of SiO_2 to CaO in the slag is 0.8. Therefore the silica pebble (93.0% SiO_2) to be added to the charge would be 130 lb. The total charge would then be as shown in Table IV.

The P_2O_5 content of the nodules plus silica pebble mixture would be about 25.8 per cent. From the TVA records on the operation of a large furnace, using a charge of the character assumed above, it will be found that about 4500 kwhr would be required per ton of P_2O_5 charged.

The Fe_2O_3 equivalent in a ton of nodules, 308 lb of coke, and 130 lb of silica pebble would yield approximately 50 lb of iron. If this appears as ferrophosphorus carrying, say, 23 per cent phosphorus, 2.7 per cent Si, 1.1 per cent Mn, the ferrophosphorus obtained would weigh 68.3 lb and the phosphorus in the ferrophosphorus would weigh 15.7 lb.

The slag formed from the ton of nodules, the coke, and the silica pebble would weigh approximately 1500 pounds, and if it carried 1 per cent P_2O_5, the phosphorus entering the slag would be about 6.55 lb.

Since the charge contained 550 lb of P_2O_5 or 240 lb of phosphorus, the estimates above lead to the conclusion that the phosphorus in the charge will be distributed as shown in Table V.

On the above basis, if 4500 kwhr are consumed per ton of P_2O_5 charged, the energy required per ton of P_2O_5 volatilized would be nearly 4956 kwhr, which would be about 11,350 kwhr per ton of phosphorus volatilized. Of course, not all phosphorus volatilized can be recovered. The actual recovery is about 96.6 per cent of that volatilized, and the energy consumption per ton of phosphorus recovered will be about 11,750 kwhr.

As pointed out above, the P_2O_5 analysis of the mixture of phosphate and silica pebble charged in the furnace is a more significant figure than is the P_2O_5 analysis of the phosphate alone when energy requirements for smelting are to be considered. If the kilowatt-hours required per ton of P_2O_5 charged be plotted as ordinates against the per cent of P_2O_5 in the phosphate-silica pebble mixture as abscissas, a nearly straight line results, and the slope of the line is such as to indicate that a per cent decrease in P_2O_5 content of the phosphate-silica pebble mixture will add about 340 kwhr to the energy required per ton of P_2O_5 charged. For example, if energy cost 3 mills per kilowatt-hour, the energy cost in smelting a phosphate-silica pebble mixture carrying 25 per cent P_2O_5 would be about $1.02 more per ton of P_2O_5 charged than it would be if the mixture carried 26 per cent P_2O_5.

TABLE III. *Assumed partial analysis of materials in the furnace charge*

	Phosphate nodules	Silica pebble	Coke
P_2O_5	27.5	—	—
CaO	39.0	0.2	—
SiO_2	24.1	93.0	6.7
Fe_2O_3	3.3	1.4	1.2
Al_2O_3	4.2	1.3	3.9
Carbon	—	—	82.6
Moisture	0.0	2.5	1.4

TABLE IV. *Charge for electric furnace*

Phosphate nodules	2000 lb
Coke	308 lb
Silica pebble	130 lb

TABLE V. *Distribution of P_2O_5 in electric furnace operation*

In Ferrophosphorus	6.5%
In Slag	2.7
Volatilized	90.8

Structural Features of a Phosphate-Smelting Electric Furnace

In the present article there is no need to discuss ordinary details of design, such as those required to meet structural stresses, provisions for expansion, foundations, etc. A few comments will be made on these features where unusual conditions are involved.

It is desirable to support the furnace so that air may circulate under it and so that any hot spots or leaks that may develop on the furnace floor may be detected.

Fig. 1 and 2 show two views of TVA Furnace No. 6, which has been in operation since 1946.

The floor of the furnace is built up of two courses of carbon blocks each 15 in. thick. The blocks were arranged with a 2-in.

clearance between them and the staggered joints then rammed with a hot carbonaceous paste. After two years and four months of operation the upper layer of blocks was replaced in the same manner. In April 1952 the floor failed, allowing ferrophosphorus and slag to tap out underneath the furnace.

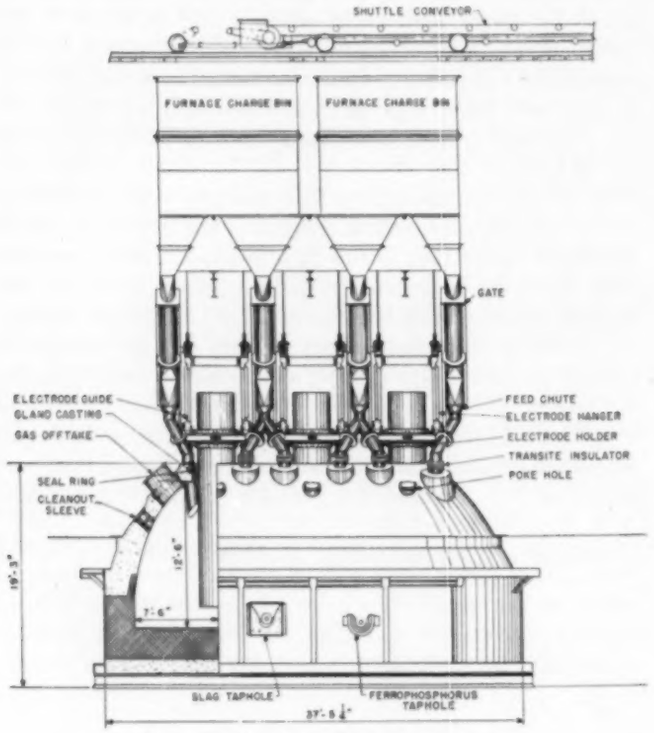

FIG. 1. Side view of Furnace No. 6

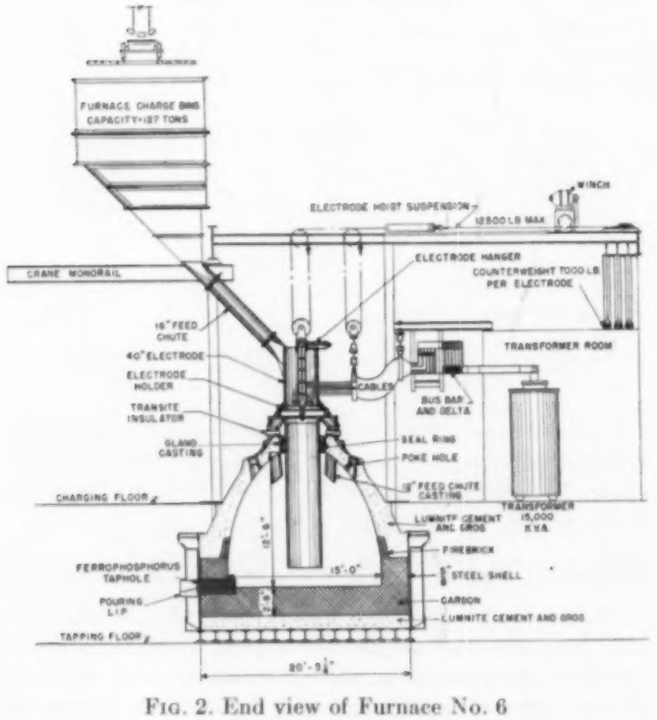

FIG. 2. End view of Furnace No. 6

The roof of the furnace is a monolithic, inverted catenary arch[3] formed by pouring a mixture of Lumnite cement and grog over a wooden form built on the job. This type of roof can be constructed at a lower cost than a ceramic masonry arch and it has several other advantages. It avoids dead space and promotes an even flow of the furnace charge downward. Also it avoids the use of structural or reinforcing steel that would not only add to the cost of the roof but would also affect adversely the electrical characteristics of the furnace. A crack that may develop in such a roof can be repaired with a cement gun and the roof can be patched without removing the furnace charge. All the TVA rectangular furnaces have now been equipped with roofs of this kind. Fig. 3 shows some details of the furnace floor and roof.

[3] S. A. HARDIN, U. S. Pat. 2,509,228 (1950).

The carbon electrodes shown in Fig. 1 and 2 are 40 in. in diameter. Either carbon or graphite electrodes may be used. The electrical resistance of graphite is somewhat less than that of carbon, and therefore a higher current density is permissible in a graphite electrode, which means a smaller electrode for a given amperage. However, graphite is more costly than carbon, and, inasmuch as the electrodes are slowly consumed in the furnace, the higher cost of graphite usually more than offsets the advantage of its greater conductivity.

The consumption of electrodes in the furnace varies with operating conditions, but in a well-designed and properly operated furnace carbon electrode consumption will fall in the range of 10 to 20 lb per ton of P_2O_5 charged to the furnace. With a 40-in. electrode, and an electrode consumption of, say, 15 lb per ton of P_2O_5 charged in a furnace drawing 12,000

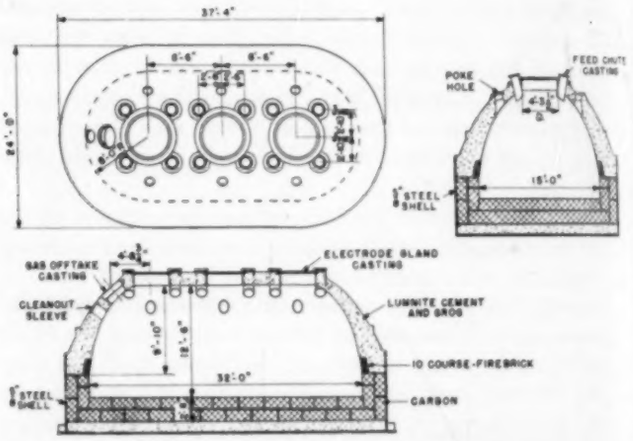

FIG. 3. Details of furnace floor and roof

kw, each electrode would move into the furnace about 4.7 in. per day.

The electrodes are suspended on steel cables that run over sheaves to an electrically operated winch. The winch is controlled either automatically or manually so as to keep a constant amperage on the furnace by raising or lowering the electrodes.

Inasmuch as conditions in an operating furnace are never static, furnace resistance is constantly changing and the electrodes must be moved up or down frequently, aside from the lowering necessary due to the consumption of electrodes at their lower ends. This constant movement of electrodes to meet furnace requirements aggravates the problem of electrode seals where the electrodes pass through the furnace roof. It is necessary to maintain a gas pressure in the furnace slightly above atmospheric in order to prevent air leakage into the furnace, and, of course it is desirable to prevent the furnace offgases from leaking out and burning around the electrodes. Gas-tight electrode seals at the furnace roof would be ideal, but no practical design for such a gas-tight seal has been developed. The best that has been done to date is to install seals that offer a considerable resistance to gas flow through them and then regulate furnace pressure so as to minimize leakage. The irregular rate of gas evolution in the furnace increases

the difficulty of close gas pressure regulation and it has not been possible completely to prevent gas leakage, although it has been reduced to tolerable limits.

Furnaces have been built with the three electrodes spaced in a row and other furnaces with the electrodes at the corners of a triangle. While both of these arrangements are satisfactory and each offers certain advantages over the other, the row spacing permits easier electrical connections and better arrangement of feed spouts and for these reasons was, until recently, used in most large furnaces. The Monsanto Chemical Company uses a triangular arrangement of electrodes, and a furnace that is triangular with rounded corners. The TVA recently built a cylindrical furnace with electrodes arranged in a triangle and a rotating hearth.

An electrode is made in sections, with threaded sockets in each end that permit the sections to be connected by threaded pins. As an electrode is consumed and lowered into the furnace, a new section is added at the upper end from time to time, and the joint between sections made tight. A carbon paste is used on the threads of the electrode and pin, and the ideal joint is one in which the electrical resistance is not greater than that encountered elsewhere in the electrode. This is a difficult chore and the making of good electrode joints is an art that is part of the "know-how" of successful furnace operation.

Carbon electrodes 40 in. in diameter are available in 100-in. lengths, and since each section weighs approximately 3.4 tons it is desirable to have crane service over the furnace to bring in and lower the electrode section when one is to be added.

Three-phase electric current is used, with one electrode on each phase. The transformers are ordinarily equipped with voltage taps on the high voltage side that permit selection of the constant voltage to be used, and the electric load on the furnace is then regulated by raising or lowering the electrodes with consequent change in current.

The bus bars from the transformers are interlaced to reduce inductance losses, and lead to a delta connection back of the furnace. Copper cables carry the current to a header, from which water-cooled copper tubes lead to the electrode clamps.

A furnace is normally equipped with at least two tap holes, one for slag and one for ferrophosphorus. On Furnace No. 6 the ferrophosphorus tap-hole block is a graphite cylinder 1 ft, 4 in. in diameter and 3 ft, 9 in. long, with a 3-in. hole at the axis. The block is inserted so that the 3-in. tap hole is at the level of the furnace floor. These tap-hole blocks may be removed and replaced without disturbance to the furnace lining, thus shortening the operating time lost when a tap-hole block must be replaced.

Various locations and types of the offgas outlet have been tried on the TVA furnaces. The original Furnace No. 1 had outlets at both ends of the furnace, but this arrangement was found to be unnecessary and costly. All furnaces were eventually equipped with a single outlet in one end of the furnace roof.

It will be recognized that a successful operation of a phosphate-smelting electric furnace plant depends not only on good functioning of the furnaces themselves but also on the proper functioning of the equipment that handles the raw material charged, the offgases, and the slag. In fact, lost time in furnace operation is more often than not due to difficulties occurring elsewhere than in the furnace itself.

Operation Data

Table VI presents average operation data for the six TVA furnaces for a six-month period in 1949 when phosphate nodules were used in the furnace charge. Furnaces No. 1, 2, 3, and 4 are nominally rated at 8000 kw, and Furnaces No. 5 and 6 at 12,000 kw but there is no logical method by which such furnaces can be rated, and, even if given a rating on the basis of design, the actual load carried on a furnace in operation will be determined by the age of the furnace, the transformer voltages and capacities available, and a number of other factors not directly related to design. The six furnaces were not of the same age in 1949; the order in which they were built new or remodeled was: No. 1, 1942; No. 5, 1942; No. 2, 1944; No. 3, 1944; No. 4, 1945; and No. 6, 1946. Furnace No. 3 had been extensively repaired in 1948 but not rebuilt. The other furnaces had been repaired in minor ways after the dates given above.

TABLE VI. *Average of six months' operating data with six furnaces*[a]

	Furnace No.					
	1[d]	2	3	4	5	6
Power load, kw	6,500	7,880	7,130	6,600	10,590	12,250
Electrode diameter, in.	30	30	30	30	40	40
Phase voltage[b]	260	274	301	206	289	291
Voltage to ground	150	158	174	119	167	168
Electrode current, amp.	15,000	17,100	14,100	20,100	22,000	26,400
Current density, amp/in.^{2}	21	24	20	28	18	21
P_2O_5 in phosphate plus silica, %	26.3	26.3	26.3	26.3	26.3	26.3
SiO_2/CaO weight ratio	0.78	0.79	0.79	0.79	0.79	0.79
P_2O_5 content of slag, %	1.2	1.0	1.3	1.1	1.1	1.0
Coke, % of theoretical[c]	102.5	102.5	102.5	102.5	102.5	102.5
Offgas temperatures, °F	685	710	695	720	785	815
Electrodes consumed, lb per ton P_2O_5 charged	14.1	14.5	10.9	23.9	14.4	18.6
Kwhr per ton P_2O_5 charged	4,400	4,330	4,230	4,660	4,510	4,520
Kwhr per ton P_2O_5 volatilized	4,840	4,710	4,670	5,110	4,930	4,910
F, power factor (by instrument)	0.96	0.97	0.97	0.92	0.96	0.92
R, ohms × 10^3 in electrode circuit	9.60	8.96	11.97	5.45	7.29	5.85
X, ohms × 10^3 in electrode circuit	2.80	2.25	3.00	2.32	2.13	2.49
Ratio $\frac{I}{E}$ in electrode circuit	100	106	81	169	132	157

[a] Only five months for No. 2 furnace.

[b] Voltage to ground $\times\sqrt{3}$.

[c] Theoretical taken as that necessary to reduce all P_2O_5 and Fe_2O_3 in charge and one-half the moisture.

[d] These data do not refer to the rotating hearth furnace now located at this position in the plant.

The operation data reflect not only the fact that the furnaces were of different ages in 1949, but, as is now known, the furnaces were all handicapped by inadequate transformer voltage ranges and by lack of depth, the latter imposed by lack of head room in the furnace building. Table VI, therefore, is a record of how the furnaces actually performed in routine operations rather than how they might have performed under more favorable conditions.

The Electrode Circuits

Inasmuch as all the furnace factors are interrelated, and together form a more or less closed system, and inasmuch as there is no satisfactory way of deriving correct relationships of the interdependent factors by theoretical considerations alone, the problem has to be approached by examination of the relationships that prevail in actual furnaces that operate successfully.

In the operation of a phosphate-smelting electric furnace

it is common practice to select a fixed voltage at the voltage taps on the high tension side of the transformer, and then to regulate the electric load on the furnace by raising and lowering electrodes. This method of furnace control is possible because the major part of the total electrode circuit resistance is located in the region between the lower end of the electrode and the carbon floor of the furnace (assuming good contacts at the electrode clamp and in the electrode joints). It follows that the voltage selected for a given power input determines the main resistance in the electrode circuit, the current necessary per electrode, and the current density in an electrode of given diameter. The lower the voltage selected for a given power input, the nearer will the electrode tip approach the furnace floor, the higher will be the electrode current, the higher will be the current density in an electrode of given diameter, and the hotter will be the reaction region around and below the tip of the electrode. It seems obvious that there are advantages in using as high a voltage as is permissible since, at a given power input, this permits the use of smaller electrodes without exceeding the allowable current density, and it avoids overheating the furnace floor. On the other hand, the slag must be hot enough to tap readily, and this means that the electrode tips must not be too far from the furnace floor. Furthermore, the voltage used must not be so high, and the corresponding resistance in the reaction region so high, as to cause appreciable leakage of current between electrodes.

All the above argument leads to the conclusion that, for a given power input and a given electrode diameter, the resistance between the electrode tips and the furnace floor should be as near as possible to the maximum permissible without causing intolerable leakage of current from electrode to electrode.

Turning now to the well-known equation:

$$EF = IR \qquad \text{(I)}$$

where E is voltage, F the power factor, I the current, and R the resistance, and considering that in well-designed phosphate-smelting furnaces the power factor is high, usually exceeding 0.96, it appears that the R in the equation will increase as the ratio I/E decreases, and since it is desirable to have R as large as permissible (not saying how large this may be) it follows that the ratio of I/E should be as small as allowable under the limitations discussed above.

In Table VI it will be seen that I/E was the smallest (81), and R therefore the largest, for Furnace No. 3 as actually operated. This furnace also had the lowest energy consumption per ton of P_2O_5 volatilized, the lowest consumption of electrode carbon, and the highest power factor. Next best results were obtained in Furnace No. 2 so far as economy of energy and power factor are concerned. Electrode consumption was not very low, but it is known that electrode consumption depends on several factors other than the I/E ratio.

Of course, the data of Table VI do not answer the question as to how low I/E and how high R could be before getting into trouble, but it seems satisfactory to say that for a furnace nominally rated at 8000 kw, such as Furnaces No. 1, 2, 3, and 4, with 30-in. carbon electrodes in a row, an I/E ratio of 80 is safe, although possibly not a minimum.

Since:

$$IEF = P \qquad \text{(II)}$$

where P is power input, if $I/E = 80$ and $F = 0.97$

$$E = 0.11352P^{\frac{1}{3}} \qquad \text{(III)}$$

$$I = 9.0816P^{\frac{1}{3}} \qquad \text{(IV)}$$

where E, I, and P refer to the single electrode circuit and P is in watts.

The temperature of the offgases can be lowered by increasing the depth of the furnaces. In the TVA plants, the furnaces first built utilized the transformers that had served the carbide furnaces in old U. S. Nitrate Plant No. 2. The phase voltage on these transformers was limited to 190, and at first the furnaces were operated at 160-phase voltage. It soon became apparent that higher voltages were desirable and as time went on the old transformers were rebuilt or replaced and higher voltages used. Then another handicap became apparent in that there was not enough head room under the electrode-handling cranes to permit building furnaces as deep as they should be in order to keep offgas temperatures low enough. It is very probable that all the TVA furnaces built prior to 1950 are too shallow and less than optimum voltages were used on all furnaces except the No. 3.

There is nothing in Table VI to indicate that an I/E ratio of 80 is the lowest that would be advantageous. The value 80 was selected only because Furnaces No. 1, 2, and 3, with I/E ratios of 100, 108, and 81, show superior results in energy economy and power factor, with Furnace No. 3 giving the best results. For reasons pointed out above, the voltage on a furnace cannot be increased indefinitely, however, and it may be that this limit would be exceeded if Furnace No. 6 were operated at a phase voltage of 400. Data are not available to answer this question.

Electrode Diameter

An electrode must be of sufficient cross section to deliver the desired current to furnace reaction zone without itself becoming too hot. The electrode receives and loses heat in several ways. The I^2R heat is liberated within the electrode all the way from the electrode clamp to the electrode tip. The electrode tip is at a high temperature and heat travels up the electrode from the tip. The electrode within the furnace is in contact with both the charge and the upward-moving, hot gases from the reaction region, and there is probably a net heat flow into the electrode. Above the furnace roof the electrode loses heat by radiation and by convection to the surrounding air. It also loses heat by conduction to the water-cooled electrode clamp. Obviously, the temperature of the electrode will rise until it loses heat as fast as it receives it. Above the furnace roof much of the electrode surface is in contact with air and the carbon will begin to oxidize at an appreciable rate in the temperature range 500-700°C. This is particularly apt to occur at the electrode joints, and any burning of the carbon at a joint lessens the electrode cross section there, with consequent further rise in temperature.

If, as proposed above, the ratio of I to E is kept constant, then both I and E vary with $P^{\frac{1}{3}}$. Since the current-carrying capacity of the electrode varies directly as the square of the electrode diameter, it might be concluded that the electrode diameter should be increased in proportion to $P^{\frac{1}{3}}$, which would result in a constant current density. This rule cannot be followed, however, for at constant current density the heat liberated per unit length of electrode is proportional to D^2, whereas the surface of the electrode increases only directly as D. It follows that even if the electrode did not receive heat by conduction upward from the hot tip, the diameter of the electrode would have to be increased somewhat more than proportional to $P^{\frac{1}{3}}$. Inasmuch as the electrode receives and loses heat in various ways, and conditions do not remain constant, it seems unlikely that an equation relating electrode

diameter to power input derived by a theoretical analysis of the situation could be as reliable as an empirical equation based on furnace experience.

The published data on the currents permissible in carbon electrodes of various sizes up to 24-in. diameter are too general to be of much help, and are not entirely consistent. Nor is it certain that electrode diameter should be chosen solely with respect to the permissible temperature in the electrode. For one thing, it is almost impossible to make up electrode joints so perfect that they have no more resistance than the solid electrode, and this would suggest that current density be kept well below that which could be used if no electrode joints were necessary. The reaction region of the furnace, around and below the lower end of the electrode, may have a form resembling the old-fashioned beehive, with the top truncated near the end of the electrode. The effectiveness of this smelting region must be related in some ways to the dimensions of the electrode. Any advantage gained here by using electrodes somewhat larger than necessary would probably more than offset the cost of the larger electrodes.

One often hears the statement that a 30-in. carbon electrode serving a phosphate-smelting furnace may be used at a current density, S, of 30 amp/in.^{2} of electrode cross section. It will be noted in Table VI that the TVA Furnace No. 4 actually operated at a current density averaging 28 for a six-month period, and there were no serious electrode difficulties noted. However, the smelting results were poor. These poor results are attributed primarily to the high I/E ratio that prevailed in this furnace. It is quite possible, of course, that the high current density also contributed to the poor results.

The data for Furnace No. 3 recorded in Table VI show this furnace, operating with a current density of 20 in the electrodes, with an I/E ratio of 81, gave excellent smelting results. Furnaces No. 2 and 3 are identical units, nominally rated at 8000 kw. If both had been operated at this rating, with an I/E ratio of 80, and assuming a power factor of 0.97, the current density would have been 21 in each case. It is evident that if electrodes 30 in. in diameter are used in a furnace of nominal rating 8000 kw, such electrodes permit a wide variation of operating conditions without any danger of overloading them.

In the case of Furnaces No. 5 and 6, which are nominally rated at 12,000 kw, it is very probable that the ratio of I/E actually used, as shown in Table VI, was far too high. The transformers on these furnaces permit a maximum phase voltage of only 300, whereas there is good reason to conclude that a phase voltage of at least 390 would give better smelting results. If each of these furnaces had been operated at its nominal rating of 12,000 kw, and an I/E ratio of 80, and assuming a power factor of 0.97, the following situation would prevail.

For 30-in. electrodes, $S = 25.7$
For 36-in. electrodes, $S = 17.85$
For 40-in. electrodes, $S = 14.45$

The electrodes actually used in Furnaces No. 5 and 6 are 40 in. in diameter, and it appears that the TVA has been even more conservative in selecting this size for the 12,000-kw furnaces than in selection of the 30-in. electrodes for the 8000-kw furnaces. If it proves feasible, as appears probable, that the larger furnaces can be operated at 390-phase voltage, then it seems that 36-in. electrodes would be amply large.

If D must be increased proportionally to $P^{\frac{1}{2}}$ in order to meet the requirement of keeping the I^2R heat release constant within the electrode, and must be increased additionally in order to keep the temperature from being too high in the larger electrodes, it appears that D should be increased somewhat more than proportionally to $P^{\frac{1}{2}}$. If it be agreed that a 30-in. electrode is ample for an 8000-kw furnace and a 36-in. electrode is ample for a 12,000-kw furnace, then:

$$D = KP^x$$

where K is a constant and x is a quantity greater than 0.25. If D is in inches and P the watts per electrode:

$$D = 0.0385P^{0.45} \qquad \text{(V)}$$

Power Factor

Well-designed electric furnaces characteristically operate with a high power factor. The several TVA furnaces operate with power factors in the range 0.89 to 0.98, and it has been noted that, in general, the lower the ratio of I/E the higher the power factor.

Electrode Spacing

The electrodes in a furnace must be spaced far enough apart to permit the furnace charge to move downward to the reactive regions below the lower ends of each electrode, and they must be far enough apart to prevent any appreciable flow of current directly from electrode to electrode. On the other hand, the electrodes must be near enough to each other so that the reactive regions touch or overlap somewhere near the furnace floor, for otherwise a dam of solid material would form at the furnace floor and interfere with the tapping of slag and ferrophosphorus. Presumably the problem of electrode spacing involves not only the kind of material to be smelted but also the size and size distribution of the lumps of raw materials in the furnace charge. The actual procedure in deciding electrode spacing appears to be that of making a reasonable guess on the basis of experience with existing furnaces and then, after the furnace is in operation, experimentally determining the sizes of coke, silica pebble, and rock phosphate that give satisfactory results.

It is almost certain that the cross section of the reactive region around and below each electrode increases from the electrode tip to the furnace floor; and from a consideration of the reasons for this increase in cross-sectional area, one may reasonably assume that the reactive region has some regular geometric form. The electrode tips are probably in contact with the melting charge but do not dip into the pool of molten slag that floats on the molten ferrophosphorus. If the power is cut off a large furnace when operating normally, the electrodes may be lowered two or three feet, whereas the slag and ferrophosphorus pool is not allowed to reach any such depth. The region directly below the electrode tip must be either void or else filled with furnace charge in such a mushy condition that it will not support the weight of the electrode.

The width and length of the furnace hearth must be such that the reaction regions do not reach the furnace walls; otherwise, excessive corrosion of the furnace walls would occur. On the other hand, the reaction regions must be near enough to the walls to prevent accumulation of masses of solid charge that would interfere with furnace tapping.

Inasmuch as there is a voltage difference between electrodes, there must be some flow of current from electrode to electrode through the coke-containing charge. This is undesirable and the magnitude of such current must be kept very small relative to the current that flows from electrode to furnace floor. Presumably this situation would set a lower limit to electrode spacing if no other requirement called for a wider spacing. If the phase voltages recorded in Table VI are com-

pared with the clearance between electrodes in the six TVA furnaces, it will be found that the voltage differences per inch of electrode clearance for the six furnaces were, respectively: 6.67; 5.08; 5.58; 4.29; 5.16; and 4.69. In a rotating-hearth furnace recently put into operation by the TVA (replacing Furnace No. 1) a voltage drop between electrodes of 7.35 per inch of clearance between electrodes causes no difficulty. From these data it would appear that the voltage drop of at least 7.35 per inch of clearance between electrodes is permissible.

As a practical matter, it is probable that the minimum clearance between electrodes is set by the necessity of having sufficient room to accommodate the electrode clamps, electrode seal rings, electrode guides, feed chutes, etc. This required clearance, plus electrode diameter, probably gives a minimum electrode spacing that is greater than the minimum that could be tolerated for electrical reasons. Even so, there should be a rough parallelism between electrode spacing and furnace capacity, inasmuch as a larger furnace requires larger electrodes, larger electrode clamps, larger feed chutes, etc., than does a smaller furnace.

In the light of present knowledge, about all that can be concluded regarding electrode spacing appears to be that the electrodes of a phosphate-smelting furnace, when arranged in a row, should be as near together as the designer can get them without exceeding a voltage drop of more than 7.35 volts per inch through the charge in the space between electrodes.

How far apart electrodes may be spaced is another problem, and, judging by the evidence that there is much overlapping of reaction regions between electrodes, the electrodes could be spaced considerably farther apart than they are in the TVA furnaces. But, obviously, there is no advantage in building a furnace larger than necessary for a given load if costs of construction and heat losses are to be kept low.

Crucible Width and Length

It appears probable that there is considerable latitude in electrode spacing, but the furnace width is a more critical matter, for, although the furnace should not be so wide as to permit solids to accumulate at crucible walls that are too cool, on the other hand the walls must not be so near the electrodes as to be exposed to the very high temperature that prevails within the reaction regions. Presumably it would not be easy to get electrodes too closely spaced, but it would be easy to get the walls too near the electrodes.

If the widths of the six TVA furnaces are compared with the electrode spacings, the following ratios will be noted for the respective furnaces: 1.91, 1.86, 1.86, 1.89, 1.88, and 1.76. As an approximation the following equation may be used:

$$W = 1.9C \qquad \text{(VI)}$$

where W is furnace width and C the electrode spacing, both, say, in inches. No reason for such a rule is apparent, but, since all six TVA furnaces operate fairly well, the rule is at least a practical one even though it may not be logical and may not be the best one that could be based on empiric information. The only validity such a rule may have resides in the fact that, for the practical reasons enumerated, the electrode spacing on a larger furnace must be greater than on a smaller furnace, and the rule would make the larger furnace proportionally wider. Furnace width, however, should logically be related to the dimensions of the reaction region and should not depend on the skill of the designer in arranging feed chutes and other structures external to the furnace.

It seems that clearances between electrodes and the furnace walls should be related to the dimensions of the reaction regions in the furnace. Unfortunately, little is known regarding the shapes and volumes of these regions. Probably the dimensions of the regions are determined by the power input, or by power input plus electrode diameter, and the information needed is the shape and volume of the reaction regions when the proper ratio of I/E and the proper electrode diameter for a given power input are used.

Inasmuch as nearly all the power delivered to a furnace is converted to heat within the furnace, there is some logic in assuming that the hearth area, A, should be proportional to power input. This is usually expressed as kw/ft² of hearth area. For example, if Furnace No. 3 were operated at 8000 kw, the power per square foot of hearth would be 25.3 kw.

As indicated above, there is no good reason for making the side wall and end wall clearances different, and therefore in any furnace with three electrodes in a row:

$$L = 2C + W \qquad \text{(VII)}$$

where L is furnace length, C electrode spacing, and W furnace width, all in the same units.

If it is a sound concept that the kilowatts of power used on a furnace divided by hearth area should not exceed some predetermined maximum, then, obviously, the values of L, C, and W can be juggled to meet this requirement. A minimum value for C can be calculated if D is known and a voltage drop of 7.35 volts per inch of charge between electrode surfaces is taken as the maximum permissible.

Thus:

$$(C - D)\,7.35 = E_p$$

or:

$$C = \frac{E_p}{7.35} + D \qquad \text{(VIII)}$$

where C and D are in inches and E_p the phase voltage.

Equations (III) and (V) may now be used to evaluate C. From equation (III):

$$E_p = 3.59\,P_t^{0.5}$$

and from equation (V):

$$D = 0.5257\,P_t^{0.45}$$

and

$$C = 0.4884\,P_t^{0.5} + 0.5257\,P_t^{0.45} \qquad \text{(IX)}$$

If the kw/ft² of hearth area, LW, is to be fixed at some predetermined value, say 25.4 kw/ft², then L, W, and the clearances, S, from electrode surfaces to side walls and end walls become fixed automatically, and it is possible to set up the equation:

$$S = \frac{-(D + C) + \sqrt{C^2 + 5.669P_t}}{2} \qquad \text{(X)}$$

Inasmuch as D, C, and P_t have been fixed for a given P_t, equation (X) gives a numerical value for S. This in turn fixes values for L and W.

Furnace Depth

The controlling factor in determining furnace depth is the permissible temperature of the furnace offgas. If this gas is to be freed of most of the dust and other solids that would prevent the condensation of high purity phosphorus, an electrostatic precipitator is ordinarily used. This limits the offgas temperature to about 800°F or less. A deep charge helps to cool the uprising gas in the furnace and to remove the coarser particles of solids. The disadvantage of a deep furnace

lies primarily in the danger of breaking the long electrodes. Fig. 2 shows a furnace of 150 in. inside height. It is probable that an additional 36 in. might be required if the higher voltage known to be desirable were actually used on this furnace.

Summary and Application of the Proposed Empiric Equations

EQUATION (III) $$E = 0.11352\ P^{\frac{1}{2}}$$

E is voltage from electrode to ground, and P is watts per electrode. This equation assumes, on the basis of operation results, that the ratio I/E should not exceed 80. It may not be the maximum value of E permissible. The equation assumes a power factor of 0.97.

EQUATION (IV) $$I = 9.0816\ P^{\frac{1}{2}}$$

I is in amperes per electrode, P in watts per electrode. The assumption is that I/E should not exceed 80 and that F is 0.97.

EQUATION (V) $$D = 0.0385\ P^{0.45}$$

D, electrode diameter, is in inches and P is in watts per electrode. This equation assumes that a 30-in. diameter carbon electrode is amply large for an 8000-kw furnace and that a 36-in. diameter carbon electrode is large enough for a 12,000-kw furnace when the I/E ratio is 80.

EQUATION (VII) $$L = 2C + W$$

L is furnace length, C electrode spacing, and W is furnace width, all in the same units. This equation must hold in any furnace if clearance from electrode surface to side wall and to end wall is the same.

TABLE VII. *Application of guide equations to several hypothetical furnaces*

Items					
Furnace load (P_t), kw	8,000	12,000	16,000	20,000	24,000
Voltage to ground (E)	185.4	227	262.2	293.1	321.1
Phase voltage (E_p) nominal	320	390	450	510	560
Electrode current (I)	14,830	18,160	20,980	23,450	25,690
Electrode diameter (D), in.	30	36	41	45	49
Electrode spacing (C), in.	74	90	103	114	125
Clearance between electrodes, in.	44	54	62	69	76
Clearance electrode to walls (S), in.	61	75	87	98	108
Furnace width (W), ft	12.7	15.5	18.0	20.1	22.0
Furnace length (L), ft	25.0	30.5	35.0	39.1	42.9
Current density, amp/in.^{2}	21.0	17.8	15.9	14.7	13.6

Remarks:

(a) The I and E values for the five hypothetical furnaces assume an $\frac{I}{E}$ ratio of 80 and a power factor of 0.97.

(b) Electrode diameters assume that 30-in. is right for an 8000-kw furnace and 36-in. is right for a 12,000-kw furnace.

(c) Electrode spacing assumes 7.35 volts drop per inch of charge between electrodes.

(d) Clearance from electrodes to side walls and end walls same, and assumes a loading of 25.4 kw/ft^2 of hearth area.

(e) L and W are derived from b, c, and d.

EQUATION (VIII) $$C = \frac{E_p}{7.35} + D$$

C is electrode spacing, E_p is phase voltage between electrodes, and D is electrode diameter, both C and D being in inches. The value 7.35 is assumed from experience to be the maximum permissible voltage drop per inch through the charge between electrodes.

EQUATION (IX) $$C = 0.4884\ P_t^{0.5} + 0.5257\ P_t^{0.45}$$

C is electrode spacing in inches, and P_t the furnace load in kilowatts. This equation is derived from equations (III), (V), and (VIII).

EQUATION (X) $$S = \frac{-(D + C) + \sqrt{C^2 + 5.669P_t}}{2}$$

S is side wall and end wall clearance. Lengths are in inches and P_t is total power on the furnace. This equation assumes 25.4 kw/ft^2 of hearth area, i.e., the coefficient 5.669 is 144/25.4.

In Table VII the several equations given above are applied to hypothetical furnaces of various nominal capacities.

F. V. Andreae's Equations

In 1933, F. V. Andreae contributed a discussion to a paper appearing in this Society's Transactions.[4] In this discussion he proposed two equations from which furnace factors may be derived, namely:

$$WDR_e = r \text{ (constant)}$$

and

$$\text{current density} = \frac{250}{D^{\frac{1}{2}}}$$

where D is electrode diameter, and R_e the optimum (maximum permissible) resistance.

The first of these equations is purely empirical and is based partly on experiments with small ferroalloy furnaces and partly on an assumption as to the path of travel of the current from the electrode to the furnace floor. The constant "r" has become known as the Andreae factor or the "peripheral ohm factor" and the equation has been used uncritically by some writers. The possible validity of the equation for a phosphate-smelting furnace has not been established.

The second of Andreae's equations is a special case of a more general equation that he published later in other journals in the form:

$$I^2 = bD^3$$

where b is supposed to be a constant. It will be observed that if b is made equal to $\left(\frac{250}{4}\pi\right)^2$, then the equation reduces to:

$$\text{current density} = \frac{250}{D^{\frac{1}{2}}}$$

as given in Andreae's original discussion. Andreae gives what purports to be a theoretical derivation of the equation

$$I^2 = bD^3$$

but he makes an assumption that is quite contrary to reason and is not in accord with observations on actual furnaces in operation. In view of these considerations, the second of Andreae's equations must be rejected except as an empirical equation that may or may not be found to have validity. At any rate it is not valid if the empirical equations proposed in the present article are valid.

[4] *Trans. Electrochem. Soc.*, **63**, 309–48 (1933).

Science and Scientists in Telecommunications

R. M. Burns[1]

Communication with the fellow members of his species was one of man's earliest activities. Indeed lower animals are said to communicate their emotional reactions by both vocal and nonlinguistic devices. One of the earliest systems of communications of primitive man was that of signal fires. According to Homeric legend, news of the fall of Troy was relayed to Greece by a series of such fires. As is well known, the American Indian used fire and smoke signals to call his warriors or announce his intentions. A recent story concerns an Indian prospecting for uranium in the wilds of Nevada, who, becoming separated from his companion, climbed up on a mountain and proceeded to build a signal fire. While nursing along a feeble blaze, he saw arise suddenly in the distance the smoke cloud of an atomic bomb explosion. Somewhat aghast, he exclaimed in admiration: "I wish I could have said that!"

In considerable contrast to the signal fires that relayed the primitive messages of the Indian, is the short-wave radio-relay system that now spans the American continent providing six television channels or thousands of voice frequency circuits. Located on seven hills between Boston and New York and 107 hills or towers between New York and San Francisco are stations which receive and retransmit a broad band in the high-frequency range where the radio waves are so short that they can be focussed like light into a narrow beam. It is this broad band capable of being sliced into a multitude of voice frequency bands or TV channels that, beamed across the country, constitutes the modern counterpart of the ancient signal fire communications. Transmission of broad-band telephony or television is not restricted, however, to radio but utilizes a nationwide network of coaxial cables which, as a result of recent developments, will be capable shortly of providing up to 7,200 voice circuits or simultaneously 2,400 voice and eight television channels. Looking further into the scientific frontier, there is prospect of sending radio frequencies through pipes known as wave guides, thus avoiding both atmospheric disturbances and increasingly crowded conditions of radio frequency spectrum.

Development of Science

These culminations in modern telecommunication systems are based upon a long series of achievements in physical science and subsequent technological inventions. Discoveries in mathematics, physics, and chemistry have contributed the general foundation on which our whole technology rests. Science, however, had its beginning long before the rise of modern technology. The intellectual stimulation of the Renaissance led in the 17th century to a broadened outlook and an interest in experimental observation. Leonardo da Vinci, with his notable achievements in engineering and science, as well as in art, and whose 500th birth anniversary has just been celebrated, appears as a transitional figure in the shift of interest toward early scientific effort. Then, later came Galileo who, by persistent experimentation of a most diversified character, established the basis for much of modern science. More of a philosopher but of scientific instincts was Francis Bacon. In his "New Atlantis," he proposed what we would now call a research institute for experimental work in all of the physical and biological sciences. Copernicus had been a contemporary of Leonardo, but it was not until Kepler during the 17th century had discovered his three laws of planetary motion and Newton had promulgated the law of universal gravitation that the heliocentric universe superseded the Ptolemaic system. The period was one of scientific ferment. The compound microscope and the telescope were of recent invention and Galileo, who made the first serious use of them, invented the thermometer and improved the clock. Robert Boyle in his experiments on the "spring of air," as he phrased it, elucidated the gas laws. Guericke invented the air pump and Torricelli the barometer. These inventions did much to improve experimental observation and initiated a trend toward reliance upon measurement which has persisted and given rise to the development of instruments of ever-increasing precision and variety as the effective tools of present-day science.

About the middle of the 17th century, experimenters began to meet for discussions of their work and ideas, giving rise to the organization of scientific societies both in England and on the Continent. The "Invisible College" mentioned as early as 1643 by Boyle became the Royal Society. John Aubrey, antiquarian and magnificent gossip, has left fascinating sketches of the activities and personal traits of his brilliant and convivial associates in that Society (1). It was in the early part of the next century that Benjamin Franklin founded the oldest scientific society in this country, the American Philosophical Society, Held at Philadelphia for Promoting Useful Knowledge—still its official name. These societies and others established later in specific fields have contributed significantly to the development of science and scientists. Wise administrators of research laboratories, recognizing this, encourage their people to publish their scientific work and attend society meetings.

The emergence of that organized body of knowledge we call science is seen to depend upon an accumulation of empirical facts and broad conceptual schemes relating these facts in interpretations of natural phenomena. This process has required two kinds of activity—experimentation and theoretical speculation, and usually by two kinds of minds not always sympathetic. Priestly discovered oxygen, but it was Lavoisier who utilized it in explaining combustion. Priestly, although so liberal in political and religious matters that he felt forced to emigrate to America, was never able to accept Lavoisier's modern ideas of combustion. Galvani, the anatomist, made the first observations of electric currents induced by the contact of a couple composed of two dissimilar metals with a frog's leg, but it was Alessandro Volta, the physicist of broader theoretical interests, who generalized the study of galvanic potentials and developed and explained the voltaic pile or battery. On the other hand, when Alexander Graham Bell invented the telephone, it was the great physicist James Clerk Maxwell of electromagnetic-light theory fame who was incredulous. Said he in a lecture after Bell had announced his discovery: "When about two years ago news came from the other side of the Atlantic that a method had been invented of transmitting by means of electricity the articulate sounds of the human voice so as to be heard hundreds of miles away from the speaker, those of us who had reason to believe that the report had some foundation of fact began to exercise our imaginations in picturing some

[1] Bell Telephone Laboratories, Inc., Murray Hill, New Jersey.

triumph of constructive skill—when at last this little instrument appeared consisting as it does of parts every one of which is familiar to us and capable of being put together by an amateur, the disappointment arising from its humble appearance was only partly relieved on finding that it was really able to talk."

Invention of the Telephone

The inventor of the telephone combined the creative imagination and methods of the scientific philosopher and the inventive genius of the practical engineer in a rather unusual degree. That he was not a specialist in electrical theory did not prevent him from applying existing electrical knowledge to new purposes. Attempting to increase the capacity of a telegraph circuit by making use of a wider band of frequencies, Bell discovered that he could transmit speech. His characteristic open-mindedness is exemplified by his advice: "Leave the beaten track occasionally and dive into the woods. You will be certain to find something that you have never seen before." Bell readily accepted evidence of new technological achievement. This is illustrated in the following news item which appeared in the *Scientific American* in December 1901: "It appears that Marconi has succeeded in sending across the Atlantic audible signals from his wireless telegraphic station in Cornwall, England, to Signal Hill, Newfoundland—a distance of 1800 miles. To be sure, these experiments have not been accepted by all scientists as conclusive. Professor Dewar does not believe that the possibility of transmitting signs across the Atlantic has been adequately demonstrated. On the other hand, Mr. Edison accepts the report as authentic and Professor (Alexander Graham) Bell has cabled his congratulations and has offered his place on the coast of Nova Scotia for future experimentation."

Fourteen years later it was possible to talk across the Atlantic although regular public service was not established until 1927. At the present time, there are 118 transoceanic telephone circuits enabling one to talk with over 96 per cent of the world's 79 million telephones located in 87 countries. Last year these overseas circuits handled over 900,000 calls. Thus is worldwide telecommunications served.

It is fortunate that Bell's successors in the technical development of the telephone carried on in his spirit of investigative enterprise. Since early in the century, technical leadership has been vested in men of scientific vision and engineering instincts who founded one of the first industrial research laboratories and staffed it with scientists and engineers. As a consequence, the empirical approach of the earlier years has given way to the more fundamentally scientific programs which are now necessary for progress in modern telephony. Basic scientific work in mathematics, physics, and chemistry are directed toward understanding the natural phenomena underlying electrical communication. Engineering studies draw upon the newly acquired scientific knowledge in the creation of new and improved telephone facilities. These programs carried on largely by Bell Telephone Laboratories for the Bell System have come to be necessary in achieving high quality telephone service at a reasonable cost.

Nature of Telephone Research

It may be of interest to describe very briefly the general nature of telephone research. H. D. Arnold, Bell Laboratories' first research director, defined research as "the effort of the mind to comprehend relationships which no one has previously known. And in its finest exemplifications it is practical as well as theoretical; trending always toward worthwhile relationships; demanding common sense as well as uncommon ability." Its three requirements "the spirit to adventure, the wit to question and the wisdom to accept and use" (2).

Research of both basic and applied character is carried on at the Laboratories in departments concerned with mathematics, electrical transmission and switching, acoustics, electronics, radio, television, physics, chemistry, metallurgy, and chemical physics. The organization of work into these specific groups is one of convenience in administration. Other arrangements could serve to cover the broad field of interest. It should be emphasized that it is the scientists, their thinking and ideas, that is important, not so much how they are organized. Organization is useful only insofar as it assists creative activity. Contributions to knowledge come from the minds of individuals, but modern science has become so vast in content, owing to the work of previous generations of scientists, that new developments depend more and more upon a sort of superpersonal group intelligence. Thus, the need arises for an integrated effort of specialists in the different fields of science underlying specific areas of human endeavor, such as telecommunications.

The present discussion will be limited to a description of a few activities mainly in basic research which in contrast to applied research or development work has neither specific practical goal nor time schedule. Its purpose is the discovery of new knowledge and incidentally the satisfaction of scientific curiosity. Experience, however, has shown that this kind of research effort is indispensable in furnishing an understanding of the problems that arise in present technology and in providing the foundation for the communications systems of tomorrow. Some of these consequences will be pointed out.

Fundamental to electrical communications are the processes of speech and hearing. Here the scientist is concerned with physiology and anatomy. How does the ear hear and what are the physical qualities of speech? An analytical study of the human voice in which intensity and frequency were plotted on a moving screen gave rise to speech patterns which could with practise be readily understood by totally deaf individuals. The results of this acoustic research have been made available for purposes of instruction of deaf children. It seems quite possible that knowledge of the structure of speech may lead ultimately to the development of voice-controlled systems and devices, such as telephone switching, and even machines like mathematical computors or typewriters. Information concerning the structure of speech is helpful in the design of both instruments and circuits for its transmission. The frequency band width for voice channels must be sufficient for high fidelity transmission, yet economical in the use of facilities.

The over-all objective in transmission engineering is accurate and rapid reproduction of signals at the distant end of transmission systems. Theory and experiment have shown that a measure of the capacity of a transmission system is the product of the frequency range and the time the system is available corrected by a factor which accounts for errors introduced by noise. Mathematical development of communication theory has undertaken to determine how much information a transmission channel can carry in one second. In this case, information is used in a technical sense to mean the logarithm of the number of different or alternative signals. One conclusion of the theory is that there is a great deal of redundancy in both speech and video signals. Ways to remove this are being studied and the ultimate application of such methods will probably be determined by costs.

Communication theory has been useful in comparing the

relative merits of alternative methods of sending information, e.g., modulation of frequency, or amplitude, or by various pulse codes. Such a study suggests that pulse code schemes would be advantageous for a transmission system utilizing wave guides in place of wires. Pulse code transmission consists of sending a sequence of signals resembling a telegraphic code and which the decoding system will translate back into voice frequencies.

Quantized transmission of signals by pulses permits a novel communication method based upon *time*-division as contrasted with the frequency-division methods used extensively in both telephony and broadcasting. In time-division hundreds, or even thousands, of different speech signals are sampled repeatedly and the samples transmitted at a rapid rate. Successive sampling cycles each occupy an interval of approximately one-ten thousandths of a second.

The role of the mathematician in telephone research is that of indispensable consultant on theoretical developments related to almost all experimental studies. Mathematical work sheds light on the feasibility of a proposed experiment, assists in the interpretation of the data obtained, and furnishes guidance for further experimentation. Mathematics may suggest the requirements to be met in a crucial experiment to establish the validity of a theoretical conclusion; it may forestall searches for the impossible. An early example of a mathematical contribution to telephony was the discovery of inductive loading of cables made independently and almost simultaneously by Dr. George A. Campbell of the American Telephone and Telegraph Company and Professor Michael Pupin of Columbia University. It has been said, and it is no exaggeration, that without mathematical research on electrical networks long-distance telephony would have been impossible.

Chemistry in Telecommunications

Some may wonder what chemists and metallurgists find to do in the communications industry. The telephone plant, which includes your telephone station set, is made up of more than ninety thousand parts, utilizing materials ranging from metals to ceramics and plastics. Nearly every material of commerce, and many special compositions of matter, find application. The telephone company sells a service rather than a product; it is a consumer of the products of the chemical and metals industries and tries to be an intelligent one. This desire and need justifies research on the relation of the properties of materials to their composition and physical and chemical structure. These properties include dielectric behavior over a wide frequency range, chemical stability and good aging characteristics, magnetic, ferroelectric and, of course, physical properties. Extremely minute traces of impurities have the greatest significance and may be necessary as in the case of certain semiconductors, or intolerable in case of some insulating materials. Certain compositions of matter are found to be useful circuit elements; they may serve as memory devices, variable resistors, temperature compensators, resistors, conductors, insulators, hard or soft magnetic materials, electronic devices, etc. Understanding by close association the purposes of communications scientists and engineers, the chemist is able to imagine and discover what compositions of matter should be of assistance in furthering these purposes. All of this provides a most stimulating atmosphere for the chemist who becomes concerned not only with the synthesis of high polymers or piezoelectric crystals, as for example polymer carbon networks (3) or synthetic quartz (4), but also he finds it his business to be curious about the chemical reactions of deterioration (5). Since good behavior and long life are desired, it is important to understand the processes of deterioration and corrosion, in order to control them. One may synthesize huge organic molecules, visible to the naked eye, then by a process of controlled deterioration (in this case dehydrogenation) remove hydrogen and oxygen, leaving only a carbon network skeleton, a substance nearly as hard as diamond. On the other hand, research on rubber deterioration reveals the role played by atmospheric ozone and the steps necessary to attain stability. One further example of chemical and metallurgical activity may be mentioned. Analytical studies of the air in telephone central offices in relation to electrical contact resistance led to the finding of a trace of an unexpected reducing gas in the neighborhood of battery rooms. This turned out to be an antimony hydride arising from storage battery grid deterioration. Examining the electrochemistry of the matter, it was evident that the standard storage battery alloy has an unfortunate tendency toward local cell action involving structural deterioration. This fact stimulated research into the hardening of lead and led to the invention of a calcium-lead alloy for battery grids. This new battery now going into the telephone plant has much longer life and will save millions of dollars eventually to telephone users. Incidentally, this battery is not suitable (at least in its present state of development) for automobile use.

Invention of the Transistor

For forty years the telephone industry has been interested in free electrons. Provided by the vacuum or electron tube, electrons have amplified the power of voice signals and made possible long distance telephony. Here as in other things the need for dependability and long life led to researches on the physics and chemistry of tube activity and life. From an understanding of the chemical reactions involved and the part played by impurities, it has been possible to develop the world's most durable electron tubes (6) of tenfold longer life performance than the ordinary tubes of home radio receivers.

Somewhat more than four years ago, mathematicians and solid state physicists at Bell Laboratories in systematic and basic studies of substances called semiconductors reached the conclusion on theoretical grounds that it should be possible to control the flow of electrons and holes through certain of these materials (particularly the element germanium), if an electromotive force is applied at barriers between electron-rich and electron-deficient regions. Going into the laboratory, it was possible to demonstrate the effect by experiment. Thus was born the transistor (7), a new electron device, which appears certain to revolutionize the electronic industry. It performs most of the functions of an electron tube and some that a tube does not. It is tiny in size, rugged in character, dependable in performance, and operates at powers 1/10,000 of that required to heat the filament of the smallest vacuum tube. One can predict many applications of the transistor in telecommunications, and in all sorts of machines, some of which now employ electron tubes. An interesting chemical aspect of the transistor is the fact that its operation depends on the controlled presence of certain impurities in the range of a few parts per hundred million parts of germanium.

The discovery of the transistor was the fruit of effort in fundamental research and an example of the logical sequence of theoretical development followed by experimental verification. More often, perhaps, new discoveries are cases of serendipity, recalling Horace Walpole's reference (8) to the

three Princes of Serendip who were always making discoveries by accident and sagacity of things they were not in quest of.

Scarcity of Scientists

It is evident from the foregoing discussion that scientists find a great deal to do in telecommunications. Much the same situation prevails in other industries, for modern society has grown more technical. The population of the country has doubled since 1900, but ten times as many engineers are employed. In addition to vastly increased research efforts by government agencies, some 3300 industrial concerns have research programs. Expenditures for research, mostly applied research, have grown sevenfold in the past twelve years (9). As the result of all of this, there has come to be a serious shortage of trained scientists. A survey of 25 leading universities by the National Academy of Sciences last year showed that there were only two-thirds as many science graduates last year as in 1950 and college enrollments indicate little prospect of improvement during the next three or four years.

What is to be done to improve the situation? The ultimate solution, not, however, providing early relief, would appear to lie in tapping that reservoir of young people known to possess sufficient mental capacity for technical training but not now going on to higher education. Last year only 58 per cent of the individuals reaching 18 years of age graduated from high school. Of the six million high school students, ten per cent have an I.Q. rating of 120 or better and thus are equipped for college work, even at the graduate level. Of the annual crop of high school graduates, only a third enter college and of those who do enter college less than two-thirds graduate. More serious is the fact that of the more brilliant college students of I.Q. 150 or better, 20 per cent leave college before graduating (10). At the graduate level, only 1.5 per cent of those who possess the intelligence to earn the doctor's degree actually do so. Of this small group, which on the average is about 3300 a year, not all by any means are in the sciences. It is to be feared further that not a high fraction of these science Ph.D.'s possess the type of creative minds necessary for fundamental research.

What characteristics are to be expected in individuals qualified for scientific work? First of all, there must be curiosity, imagination, originality, and capacity for independent thinking. Objectively, reasonable skepticism and particularly ability to consider ideas on their merits alone are indicative of the type of free mind necessary in research. There must be that rigorous intellectual honesty that accepts data for what they are and excludes wishful thinking in drawing conclusions. Finally, the potential scientist must possess unusual capacity for hard work—patient, persistent hard work characteristic of a disciplined mind. Geneticists may agree that the bases for these qualities are inherited, but there can be little doubt that their fruition depends upon stimulation by suitable environmental influences.

The Training of More Scientists

Why do bright students fail to go to college or quit before graduation if they do go? The principal reason appears to be lack of interest, and this must be traced to a failure of parents to encourage intellectual attainment, but in greater measure to the prevalence of indifferent teaching. The scarcity of gifted teachers capable of inspiring a keen interest in science is the real difficulty. This is particularly serious at the high school level since it is there that the majority of young people choose their careers. Some secondary schools are actually unable to get science teachers; in many others, only one science course is offered and the teacher required to give this course may have little or no knowledge of the subject and certainly no professional interest in it. Is it any wonder then that there is a continuing relative decline in the selection of the physical sciences for careers? Yet science is exciting and should fascinate students if skillfully presented. Here the economic problem comes in as shown by the fact that many good teachers are finding it necessary to accept better paid positions in other fields. If, on the other hand, the salaries of deserving teachers were substantially increased, more people with teaching talent would be induced to prepare for the teaching profession, unless discouraged by the dullness of courses in educational theory and practise which, unfortunately, are generally required of those who are to teach in the secondary as well as the primary schools. The techniques of teaching taught in these courses are doubtless useful, but the intellectual and cultural radiation of the broadly educated teacher, enthusiastic about his field of specialization, is certain to be a more potent factor in stimulating young people. Probably teachers are born that way; they need not be scientists unless required to train science students at the graduate level. And, of course, not all scientists are good teachers.

The first step toward increasing the supply of scientists is to identify at an early enough age those who have the capacity for research careers, then to attract and sustain their interest, and finally to provide the proper educational training. Much needs to be done on all of these aspects. Because of the vastly increased body of scientific knowledge and because of its great importance in the advancement and, indeed, the survival of western civilization, the time has come when the teaching of science should be undertaken in the elementary school along with reading, writing, and arithmetic. Science should be continued and expanded through the secondary schools. Valuable time and opportunity for science teaching are lost at the high school level at present, as is shown by the fact that elementary science courses must be repeated in college. Probably one difficulty is that high school courses are pitched at a level for the average intellect. It cannot be emphasized too strongly that it is the *bright* student who needs and should engage the principal attention of our educational system. President Dodds of Princeton has put the problem succinctly: "At the risk of being misunderstood, I assert that for the youth of superior minds and promise, mass education is a contradiction in terms. Our democracy will fall and deserve to when it really concludes that there must be no aristocracy of brains; that all of whatever aptitudes, tastes and capacities must have the same treatment" (11).

There are many who contend, with good reason, that the humanities are neglected; engineering schools, however, are recognizing the importance and making provision for the inclusion of broader cultural subjects in their curriculae. In making provision for considerably more scientific training, there need be no curtailment in instruction in the basic humanities. There should be time for both in a modernized curriculum properly presented at the right time to the right people.

In conclusion it should be emphasized that science has become the predominant influence in world affairs. It is a time of rapidly growing scientific competition between free and totalitarian dominated peoples. Our own internal economy and indeed our national survival may well depend upon our having more scientists and smarter scientists than any potential combination of unfriendly powers.

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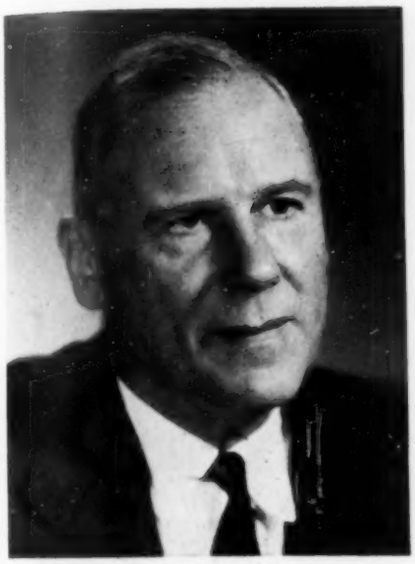
Officers to Start New Terms at New York Meeting



ROBERT J. MCKAY

HANS THURNAUER

As a result of the recent annual election, in which the voting is by mail ballot, Robert J. McKay became the new President of the Society and Hans Thurnauer has been elected Vice-President. The new officers will be presented to the members and will formally take office at the annual business meeting of the Society on Monday, April 13, during the New York Meeting.

Mr. McKay, Chemical Engineer in charge of Plating Sales and Development, International Nickel Company, New York, will replace Dr. J. C. Warner, President of Carnegie Institute of Technology. Dr. Warner, as Past President, will continue as a member of the Board of Directors.

Dr. Hans Thurnauer, Vice-President and Director of Research of American Lava Corporation, Chattanooga, will start his first term as Society Vice-President and will serve with the two previously elected Vice-Presidents, Marvin J. Udy and H. H. Uhlig.

See Your Program Booklet

Complete details of the New York Meeting schedule will be found in the Program Booklet which has been mailed to all Society members. In addition, a special entertainment program, theater ticket list, and general information bulletins about New York have been sent separately. Dates of the meeting are April 12–16, with headquarters at the Statler Hotel.

Guest Speakers

Dr. Max A. Lauffer, Research Professor of Biophysics, University of Pittsburgh, will speak at the Monday night dinner, April 13. This dinner is given in connection with the symposium on the Application of Electrochemistry to Biology and Medicine.

Dr. John R. Dunning, Dean of the School of Engineering, Columbia University, will address the Society Luncheon on Monday noon, April 13.

New York Technical Program

Monday, April 13, 1953

9:00 A.M.—Formal Opening of the 103rd Convention with Introduction by General Chairman Harry R. Copson, and response by President-Elect Robert J. McKay.

Electric Insulation

Wednesday, April 15, 1953
R. A. Ruscetta presiding

9:00 A.M.—"The Use of Asbestos in Electric Insulation" by Oliver Bowles, U. S. Department of the Interior, Bureau of Mines, Constructions and Chemical Materials Branch, Washington, D. C.

9:45 A.M.—"New Developments in the Manufacture of Synthetic Fiber Paper" by Hanns F. Arledter, Hurlbut Paper Company, South Lee, Mass.

10:15 A.M. "Positive D-C Corona on Polyethylene-Insulated Wire in Air" by D. S. Rodbell and J. B. Whitehead, The Johns Hopkins University, Department of Electrical Engineering, Baltimore, Md.

10:45 A.M.—"The Surface and Volume Loss on Dielectrics Under Alternating Stress" by J. J. Chapman, The Johns Hopkins University, Baltimore, Md.

11:15 A.M.—"Polyelectrolytes" by W. P. Hohenstein and H. Mark, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Electric Insulation (cont'd.)
C. Frank Miller presiding

2:00 P.M.—"The Color of the Tantalum Oxide Film Predicts Certain Characteristics of the Tantalum Electrolytic Capacitor" by A. F. Torrisi, Capacitor Department, General Electric Company, Hudson Falls, N. Y.

2:45 P.M.—"Quinones as Ion Source in Hydrocarbons" by Andrew Gemant, Engineering Laboratory and Research Department, The Detroit Edison Company, Detroit, Mich.

3:15 P.M.—"Stability of 2,6-di-tert-butyl-para-cresol Inhibited Trans-

former Oil in an Arc" by R. N. Hazelwood, K. Oura, and R. M. Frey, Line Material Company, South Milwaukee, Wis.

3:45 P.M.—"The Electrical Properties of Selected Liquids" by Thomas D. Callinan, Naval Research Laboratory, Washington, D. C.

Electronics—Luminescence

Monday, April 13, 1953
Horace H. Homer presiding

9:15 A.M.—Introductory remarks by Arthur L. Smith.

9:20 A.M.—"Radioluminescence of Phosphors" by James H. Schulman, Metallurgy Division, Naval Research Laboratory, Washington, D. C.

10:05 A.M.—"Preliminary Studies on Luminescence and Tenebrescence of Synthetic Hackmanite-Like Materials" by Russell D. Kirk, Metallurgy Division, Naval Research Laboratory, Washington, D. C.

10:25 A.M.—"Luminescence of the System β $Zn_3(PO_4)_2$-$Cd_3(PO_4)_2$:Mn" by Arthur L. Smith and A. D. Power, Tube Department, Radio Corporation of America, Lancaster, Pa.

10:50 A.M.—"Luminescence of Calcium Fluoride Activated by Cerium and Manganese" by Robert J. Ginther, Metallurgy Division, Naval Research Laboratory, Washington, D.C.

11:10 A.M.—"New Manganese-Activated Fluoride Phosphors" by Arthur L. Smith, Tube Department, Radio Corporation of America, Lancaster, Pa.

11:30 A.M.—"The Measurement of Quantum Efficiency of Fluorescent Lamp Phosphors" by Charles W. Jerome, Sylvania Electric Products Inc., Salem, Mass.

11:50 A.M.—"The Oxidation States of Europium in Alkaline-Earth Oxide and Sulfide Phosphors" by P. Jaffe and E. Banks, Department of Chemistry, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

Electronics—Luminescence (cont'd.)
Robert J. Ginther presiding

2:00 P.M.—"One Dimensional Disorder in ZnS Single Crystals" by L. W. Strock and V. A. Brophy, Physics Laboratories, Sylvania Electric Products Inc., Bayside, N. Y.

2:30 P.M.—"Vibrational Fine Structure in Luminescence Emission" by Clifford C. Klick, Metallurgy Division, Naval Research Laboratory, Washington, D. C.

2:50 P.M.—"The Constitution of the Green and Blue Luminogene Centers of Zinc Sulfide Phosphors Activated with Copper" by Edmond Grillot, Laboratoire de Luminescence, Faculté des Sciences (P.C.B.), Paris, France.

3:20 P.M.—"Fluorescence and Phosphorescence of ZnS Phosphors" by Keith H. Butler, Sylvania Electric Products Inc., Salem, Mass.

3:40 P.M.—"Factors Affecting the Emission Spectra of Manganese-Activated Phosphors" by Arthur L. Smith, Tube Department, Radio Corporation of America, Lancaster, Pa.

4:10 P.M.—"Radiationless Electron Transitions in the Lattice of Crystalline Phosphors" by Michael Schön, OSRAM Research Laboratory, Mosbach Branch, Baden, Germany.

Tuesday, April 14, 1953
Electronics—Luminescence (cont'd.)
Arthur L. Smith presiding

9:30 A.M.—"Copper-Activated Zinc Sulfide Phosphors with Yellow and Red Emission" by H. C. Froelich, Lamp Development Laboratory, General Electric Company, Nela Park, Cleveland, Ohio.

9:50 A.M.—"Copper-Activated Zinc Sulfide Phosphors with Trivalent Substituents" by H. C. Froelich, Lamp Development Laboratory, General Electric Company, Nela Park, Cleveland, Ohio.

10:10 A.M.—"The Copper Content of H_2S-Fired ZnS:Cu Phosphors" by H. C. Froelich and F. W. Pikus, Lamp Development Laboratory, General Electric Company, Nela Park, Cleveland, Ohio.

10:30 A.M.—"Electroluminescent Zinc Sulfide Phosphors" by Horace H. Homer, Richard M. Rulon, and Keith H. Butler, Sylvania Electric Products Inc., Salem, Mass.

11:00 A.M.—"Electroluminescence of Insulated Phosphor Particles" by Laurence Burns, Sylvania Electric Products Inc., Salem, Mass.

11:20 A.M.—"Luminescence of Electroluminescent ZnS Phosphors Under the Influence of Step-Functions of Unidirectional Field" by John F. Waymouth and Francis Bitter, Sylvania Electric Products Inc., Salem, Mass.

11:40 A.M.—"Electroluminescent Sulfide Phosphors, I. Chemical Nature" by P. Zalm, H. A. Klasens, and G. Diemer, Research Laboratories, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.

12:10 P.M.—"Electroluminescent Sulfide Phosphors, II. Electrical and Optical Measurements" by C. Diemer and P. Zalm, Research Laboratories, N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.

Round Table
Electronics—Luminescence
Luke Thorington presiding

2:00–5:00 P.M. General discussion.

Electronics—Rare Metals

Thursday, April 16, 1953
A. U. Seybolt presiding

9:30 A.M.—"Investigation of Some Factors Related to the Deposition of Boron" by Russell H. Atkinson and John C. R. Kelly, Jr., Research Department, Westinghouse Electric Corporation, Bloomfield, N. J.

10:00 A.M.—"Improving the Purity of Powder Metallurgy Molybdenum" by John C. R. Kelly, Jr., and Alan G. Caterson, Research Department, Westinghouse Electric Corporation, Bloomfield, N. J.

10:30 A.M.—"Diffusion of Cobalt in Molybdenum" by E. S. Byron and V. E. Lambert, Westinghouse Electric Corporation, Bloomfield, N. J.

11:00 A.M.—"Kilogram Scale Reductions of Vanadium Pentaoxide to Vanadium Metal" by Arthur P. Beard and Donald D. Crooks, Knolls Atomic Power Laboratory, General Electric Company, Schenectady, N. Y.

11:30 A.M.—"Mechanical Properties of High Purity Vanadium" by C. M. Brown, Electro-Metallurgical Company, Niagara Falls, N. Y.

Electronics—Rare Metals (cont'd.)
Donald M. Wroughton presiding

2:00 P.M.—"Lithium as a Reducing Agent in the Production of Other Metals" by R. R. Rogers and G. E. Viens, Mines Branch, Department of Mines and Technical Surveys, Division of Mineral Dressing and Process Metallurgy, Ottawa, Ontario, Canada.

2:30 P.M.—"Preparation of a New Series of Alkali Titanium Halides of Lower Valent Titanium" by Joseph M. Sherfey and Abner Brenner, National Bureau of Standards, Washington, D. C.

3:00 P.M.—"The Preparation of Zirconium Metal by Arc Dissociation of Halides" by James H. Moore, National Research Corporation, Cambridge, Mass.

3:30 P.M.—"Studies on the Mechanism of Hydrogen Reaction with Zirconium" by Earl A. Gulbransen and

Kenneth F. Andrew, Westinghouse Research Laboratories, East Pittsburgh, Pa.

Electronics—Phosphor Screen Application

Wednesday, April 15, 1953
W. J. Hindman presiding

9:00 A.M.—Introductory Remarks by A. E. Hardy.

9:05 A.M.—"Milling of Phosphors" by A. Steadman, Allen B. DuMont Laboratories, Inc., Clifton, N. J.

9:25 A.M.—"Particle Size Distribution of Phosphors" by Martha J. Bergin and Keith H. Butler, Sylvania Electric Products Inc., Salem, Mass.

9:40 A.M.—"Determination of Size Distribution of Solid Aggregates and Phosphors in Suspension" by W. Rublack, Radio Corporation of America, Victor Division, Marion, Ind.

10:00 A.M.—"Potassium Silicates for the Preparation of Cathode Ray Screens" by Wm. Stericker, Philadelphia Quartz Company, Philadelphia, Pa.

10:20 A.M.—"The Measurement of the Dry Adherence of Kinescope Screens" by H. Duecker and C. T. Lattimer, Radio Corporation of America, Victor Division, Marion, Ind.

10:45 A.M.—"Streaming Potential Studies of Phosphors, Glasses, and Gels" by George L. Schnable and J. Fred Hazel, University of Pennsylvania, Philadelphia, Pa.

11:05 A.M.—"On the Collection of Secondary Electrons in a Kinescope" by G. P. Kirkpatrick, Tube Department, Radio Corporation of America, Lancaster, Pa.

11:15 A.M.—"Polarographic Determination of Cadmium and Zinc in Zinc Sulfide-Cadmium Sulfide Phosphors" by Samuel B. Deal, Tube Department, Radio Corporation of America, Lancaster, Pa.

11:25 A.M.—"A Study of Metallic Impurities Through Oxide Cathode Coatings" by Armand P. LaRocque and Gerald K. Clymer, Tube Development Laboratory, Philco Corporation, Lansdale, Pa.

11:40 A.M.—"The Preparation of Phosphor Screens for Color Television Tubes" by Sidney Levy and Albert K. Levine, Sylvania Electric Products Inc., Bayside, N. Y.

Round Table
Phosphor Screen Application
R. B. Snyder presiding

2:15–4:00 P.M.—General discussion.

Electronics—Semiconductors

Tuesday, April 14, 1953
H. R. Harner presiding

2:00 P.M.—Opening Address by H. R. Harner.

2:20 P.M.—"Resistivity Striations in Germanium Metal" by Paul R. Camp, Radio Corporation of America, RCA Laboratories Division, Princeton, N. J.

2:50 P.M.—"Phenomena Observed in the Melting and Solidification of Germanium" by S. E. Bradshaw, Research Laboratories, General Electric Company, Ltd., Wembly, England.

3:20 P.M.—"Germanium Metal Preparation and Its Effect on Diode Characteristics" by A. S. Rugare. General Electric Company, Clyde N. Y.

3:50 P.M.—"Application of Zone-Melting Techniques to the Purification of Rare Metals" by W. G. Pfann, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

4:20 P.M.—"Vapor Phase Deposition of Germanium by Reduction of the Chlorides" by W. E. Medcalf, R. K. Riel, and C. E. Smith, Eagle-Picher Research Laboratories, Joplin, Mo.

Wednesday, April 15, 1953
Electronics—Semiconductors
J. B. Merrill presiding

9:30 A.M.—"Electrical Properties of Semiconducting Al-Sb" by R. K. Willardson, A. C. Beer, and A. E. Middleton, Battelle Memorial Institute, Columbus, Ohio.

10:00 A.M.—"Preparation and Properties of Lead Telluride Single Crystals" by Edward L. Brady, Research Laboratory, General Electric Company, Schenectady, N. Y.

10:30 A.M.—"Influence of Composition and Temperature on the Resistivity of Some Alkaline Earth Titanates" by E. K. Weise, University of Illinois, Urbana, Ill., and I. A. Lesk, General Electric Company, Electronics Laboratory, Syracuse, N. Y.

11:00 A.M.—"The Nitrides of Chromium and Chromium-Titanium Alloys—New Film-Type Resistance Elements" by E. R. Olson, E. H. Layer, and A. E. Middleton, Battelle Memorial Institute, Columbus, Ohio.

11:30 A.M.—General Discussion.

Wednesday, April 15, 1953
Electronics—Semiconductors
Martin F. Quaely, presiding

2:00 P.M.—"Radiochemical Activity Analysis and Germanium Purification" by George H. Morrison, Physics Laboratories, Sylvania Electric Products Inc., Bayside, N. Y.

2:25 P.M.—"Applications of Radioisotopes in the Study of Semiconductors" by J. D. Struthers, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

2:50 P.M.—"Interaction of Hole and Electron Currents in Point Contact Transistor Structures" by Maynard H. Dawson, Sylvania Electric Products Inc., Newton Highlands, Mass.

3:15 P.M.—"Frequency Variations of Junction-Transistor Parameters" by R. L. Pritchard, Research Laboratory, General Electric Company, Schenectady, N. Y.

Electro-Organic Chemistry

Tuesday, April 14, 1953
Christopher Wilson presiding

9:00 A.M.—"The Electrolytic Reduction of Diisopropyl Ketone" by Sherlock Swann, Jr., D. K. Eads, and L. H. Krone, Jr., Department of Chemistry, University of Illinois, Urbana, Ill.

9:20 A.M.—"Reduction of Furfural: Structure of the Resin" by Donald Staker and Christopher Wilson, Ohio State University, Columbus, Ohio.

9:40 A.M.—"The Electrolytic Reduction of a Branched Chain Aliphatic Aldehyde in Acid Solution" by Sherlock Swann, Jr., E. I. Onstott, and F. H. Baastad, Department of Chemistry, University of Illinois, Urbana, Ill.

10:00 A.M.—"Attempts at the Electrolytic Initiation of Polymerization" by H. Z. Friedlander, Sherlock Swann, Jr., and C. S. Marvel, Department of Chemistry, University of Illinois, Urbana, Ill.

10:20 A.M.—"The Electrolysis of Salts of Fatty Acids in the Same Anhydrous Acids" by Stefan Goldschmidt, Institut der Technicischen Hochschule, München, Germany.

10:40 A.M.—"Studies on the Improvement of the Electrolytic Process of the Preparation of Organic Compound: Electrolytic Reduction of Nitrobenzene to Hydrazobenzene" by Kiichiro Sugino and Taro Sekine, Laboratory of Organic Electrochemistry, Tokyo Institute of Technology, Chiba, Japan.

11:00 A.M.—"Studies on the Mechanism of the Electrolytic Formation of Perchlorate" by Kiichiro Sugino and Shigeru Aoyagi, Laboratory of Organic Electrochemistry, Tokyo Institute of Technology, Chiba, Japan.

Electro-Organic Chemistry (cont'd.)
Stanley Wawzonek presiding

2:15 P.M.—"Effect of Chain Branching on Electrochemical Carbon-Halogen Fission—Possible Mechanism for the Process" by Philip J. Elving and Joseph M. Markowitz, University of Michigan, Ann Arbor, Mich., and Isadore Rosenthal, Pennsylvania State College, State College, Pa.

2:35 P.M.—"Polarography of Thioglycolic Acid" by D. L. Leussing and I. M. Kolthoff, School of Chemistry, University of Minnesota, Minneapolis, Minn.

2:55 P.M.—"A Millicoulometer Method for the Determination of Polarographic *n*-Values" by Thos. De Vries and James Kroon, Department of Chemistry, Purdue University, Lafayette, Ind.

3:15 P.M.—"The Behavior of Organic Compounds at the Dropping Mercury Electrode in Anhydrous Methansulfonic Acid" by S. Wawzonek and D. F. Thomson, Department of Chemistry and Chemical Engineering, State University of Iowa, Iowa City, Iowa.

3:35 P.M.—"Polarography in Nonaqueous Solvents—The Use of Glycerol at Elevated Temperatures" by Thos. De Vries and D. B. Bruss, Department of Chemistry, Purdue University, Lafayette, Ind.

3:55 P.M.—"The Polarographic Behavior of Zinc in Strongly Alkaline Solutions" by Thedford P. Dirkse, Department of Chemistry, Calvin College, Grand Rapids, Mich.

4:15 P.M.—"Polarographic Determination of the System, *o*-Nitroanisole, *o*-Chloronitrobenzene, and *o*-Nitrophenol" by Shinichi Kikuchi and Kenichi Honda, Laboratory of Electrochemistry and Photochemistry, Institute of Industrial Science, University of Tokyo, Chiba, Japan.

4:35 P.M.—"Effect of Structure on the Polarographic Reduction of Iodo-Compounds" by Eugene L. Colichman, Livermore Research Laboratory, California Research and Development Co. Livermore, Calif.

Wednesday, April 15, 1953
Electro-Organic Chemistry (cont'd.)
Round Table
Anodic Reactions
Sherlock Swann presiding

9:00 A.M.–12:00 M.—Round-Table Discussion. Speakers: W. Urry, C. Wilson, M. Janes, R. P. Linstead, B. C. L. Weedon, G. W. Thiessen, and W. MacNevin.

Electrothermics

Monday, April 13, 1953
Laboratory and Commercial Equipment, Processes, and Products
J. S. Dewar presiding

9:30 A.M.—"Inert Atmosphere Forging" by Carl Kolbe, Metallurgy Research Department, General Electric Company, Schenectady, N. Y.

10:00 A.M.—"Possibilities of Making Steel from Ore in a Duplex Electric Furnace Operation" by H. S. Newhall, Pittsburgh Lectromelt Furnace Corporation, Pittsburgh, Pa.

10:30 A.M.—"Flexible Leads for Low Frequency Electric Arc Furnaces" by M. Eaton, Shawinigan Chemicals Limited, Shawinigan Falls, Canada, and S. B. Thomas, Northern Electric Company Limited, Montreal, Canada.

11:00 A.M.—"Energy Losses from Furnaces and the Concept of Efficiency" by Victor Paschkis, Department of Mechanical Enginering, Columbia University, New York, N. Y.

11:30 A.M.—"Induction Heating—Design of Inductors" by Anthony Vescuso, Lepel High Frequency Laboratories, Inc., New York, N. Y.

Electrothermics (cont'd.)
Laboratory and Commercial Equipment, Processes, and Products
I. E. Campbell presiding

2:00 P.M.—"Status of Research on Electromagnetic Levitation of Solid and Molten Metals" by D. M. Wroughton, G. Comenetz, and P. H. Brace, Westinghouse Electric Corporation, Pittsburgh, Pa., and John C. R. Kelly, Jr., and E. C. Okress, Westinghouse Electric Corporation, Bloomfield, N. J.

2:30 P.M.—"Arc Melting as a Laboratory Tool" by H. R. Ogden and R. I. Jaffee, Battelle Memorial Institute, Columbus, Ohio.

3:00 P.M.—"Vacuum Arc Melting—Controlling the Purity of Molybdenum" by G. W. P. Rengstorff, Battelle Memorial Institute, Columbus, Ohio.

3:30 P.M.—"An Apparatus for Determination of the Solidus Temperatures of High-Melting Alloys" by R. A. Oriani and T. S. Jones, General Electric Research Laboratory, Schenectady, N. Y.

4:00 P.M.—"The Use of Radiant Energy in High Temperature, High Speed, or Controlled Atmospheric Heating" by C. F. Powell, Battelle Memorial Institute, Columbus, Ohio.

4:30 P.M.—"Construction of Molybdenum Wound Furnaces" by D. F. Taylor, Fansteel Metallurgical Corporation, North Chicago, Ill.

Tuesday, April 14, 1953
Electrothermics (cont'd.)
Laboratory and Commercial Equipment, Processes, and Products
C. H. Chappell presiding

9:30 A.M.—"Hot Pressing Furnaces" by J. A. Upper, Norton Company, Niagara Falls, Canada.

10:00 A.M.—"Electrical Conduction by Columns of SiC Grit" by G. H. Fetterley, Norton Company, Niagara Falls, Canada.

10:30 A.M.—"The effect of Color and Crystal Size of Silicon Carbide on the Exponent Characteristics of Varistor Disks" by C. J. Frosch, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

11:00 A.M.—"The Electrical Resistivity of Heat-Treated Carbon Blacks" by W. D. Schaeffer, W. R. Smith, and M. H. Polley, Godfrey L. Cabot, Inc., Cambridge, Mass.

Theoretical Electrochemistry

Monday, April 13, 1953
Symposium on Application of Electrochemistry to Biology and Medicine
General Chairman—
Detlev W. Bronk, Ph.D.
Program Chairman—
Walter J. Hamer, Ph.D.
Detlev W. Bronk presiding

9:15 A.M.—Introductory Remarks by Detlev W. Bronk, Johns Hopkins University, Baltimore, Md.

9:30 A.M.—"Molecular Structure and Diffusion in Aqueous Solution" by L. G. Longsworth, Ph.D., The Rockefeller Institute for Medical Research, New York, N. Y.

10:10 A.M.—"Activity Coefficients of Some Sodium and Potassium Phosphates in Reference to Biological Cation Concentration Gradients" by Fred M. Snell, M.D., Ph.D., Department of Biology, Massachusetts Institute of Technology, Cambridge, Mass.

10:50 A.M.—"The Galvanic Cell" by T. Shedlovsky, Ph.D., The Rockefeller Institute for Medical Research, New York, N. Y.

11:35 A.M.—"Electrochemical Phenomena in Plant Cells" by L. R. Blinks, Ph.D., Hopkins Marine Station, Stanford University, Pacific Grove, Calif.

Symposium on Application of Electrochemistry to Biology and Medicine (cont'd.)
Theodore Shedlovsky, Ph.D., presiding

2:00 P.M.—"Electrical Signs of Epileptic Discharge" by Herbert H. Jasper, M.D., Montreal Neurological Institute, McGill University, Montreal, Canada.

2:45 P.M.—"Electroencephalographic Localization of Brain Tumors" by B. K. Bagchi, Ph.D., The Neuropsychiatric Institute, University Hospital, University of Michigan, Ann Arbor, Mich.

3:30 P.M.—"Review of Electrophoresis into the Human Skin" by Harold A. Abramson, M.D., New York, N. Y.

4:15 P.M.—"Some Problems Arising in the Clinical Interpretation of Electrocardiograms" by Franklin D. Johnston, M.D., Heart Station, Department of Internal Medicine, University of Michigan Medical School, Ann Arbor, Mich.

Tuesday, April 14, 1953
Symposium on Application of Electrochemistry to Biology and Medicine (cont'd.)
L. R. Blinks, Ph.D., presiding

9:00 A.M.—"Membrane Potentials in the Donnan Equilibrium, II" by David I. Hitchcock, Ph.D., and Alexander Mauro, Ph.D., Laboratory of Physiology, Yale University School of Medicine, New Haven, Conn.

9:45 A.M.—"Membranes, Their Electrochemistry, and Their Use in Model Studies of Biological Interest" by Karl Sollner, Ph.D., Sheldon Dray, M.D., Eugene Grim, Ph.D., and Rex Neihof, Ph.D., National Institute of Arthritis & Metabolic Diseases, National Institutes of Health, Public Health Service, Federal Security Agency, Bethesda, Md.

10:30 A.M.—"On the Nature of the Membrane Potential of Frog Nerve" by R. Lorente de Nó, M.D., The Rockefeller Institute for Medical Research, New York, N. Y.

11:15 A.M.—"Dynamic Negative Resistance in Statically Stable Membranes" by Otto H. Schmitt, Ph.D., Departments of Physics and Zoology, University of Minnesota, Minneapolis, Minn.

Symposium on Application of Electrochemistry to Biology and Medicine (cont'd.)
Herbert H. Jasper, M.D., presiding

1:45 P.M.—"The Implementation of Electrical Energy by Paired Half-Centers as Revealed by Structure and Function" by Robert Gesell, M.D., Physiology Laboratory, University of Michigan, Ann Arbor, Mich.

2:30 P.M.—"The Effects of Changes in the Internal Composition of the Single Nerve Fiber on the Bioelectric Potential" by Harry Grundfest, Ph.D., Department of Neurology, College of Physicians and Surgeons, Columbia University, New York, N. Y.

3:15 P.M.—"Ions, Potentials, and the Nerve Impulse" by Kenneth S. Cole, Ph.D., Naval Medical Research Institute, National Naval Medical Center, Bethesda, Md.

4:00 P.M.—"The Molecular Basis of Nerve Action Potentials" by David Nachmansohn, M.D., Department of Neurology, Columbia University, College of Physicians and Surgeons, New York, N. Y.

Wednesday, April 15, 1953
Symposium on Application of Electrochemistry to Biology and Medicine (cont'd.)
Duncan A. MacInnes, Ph.D., presiding

9:00 A.M.—"Light Scattering Studies on Kinetic and Equilibrium Relations in the Formation of Mercaptalbumin Mercury Dimer" by John T. Edsall, M.D., Ephraim Katchalski, Ph.D., and Robert H. Maybury, Ph.D., University Laboratory of Physical Chemistry, Related to Medicine and Public Health, Harvard University, Boston, Mass.

9:40 A.M.—"Ion Exchanger Electrodes" by George Scatchard, Ph.D., Department of Chemistry, Massachusetts Institute of Technology, Cambridge, Mass.

10:20 A.M.—"The Determination of the Activity of Small Ions in Protein Solutions with Collodion Membrane Electrodes" by Charles W. Carr, Ph.D., Department of Physiological Chemistry, University of Minnesota, Minneapolis, Minn.

10:55 A.M.—"Hydrogen Ion Titration Curves of Proteins" by Charles Tanford, Ph.D., Department of Chemistry, State University of Iowa, Iowa City, Iowa.

11:30 A.M.—"Some Aspects of Bioelectrical Phenomena" by W. J. V. Osterhout, Ph.D., The Rockefeller Institute for Medical Research, New York, N. Y.

1:45 P.M.—"Chemical Specificity in Biological Interactions" by Edwin J. Cohn, Ph.D., Douglas M. Surgenor, Ph.D., Frank R. N. Gurd, Ph.D., Margaret J. Hunter, Ph.D., and Walter L. Hughes, Jr., Ph.D., University Laboratory of Physical Chemistry, Related to Medicine and Public Health, Harvard University, Boston, Mass.

2:25 P.M.—"Polarographic Study of Proteins and Their Degradation Products, IV. The Behavior of Various Fractions of Plasma Proteins" by Otto H. Müller, Ph.D., School of Medicine, Department of Physiology, State University of New York, Medical Center, Syracuse, N. Y.

3:00 P.M.—"Dielectric Studies in Concentrated Protein Solutions" by J. L. Oncley, Ph.D., and H. M. Dintzis, Ph.D., University Laboratory of Physical Chemistry, Harvard University, Boston, Mass.

3:40 P.M.—"A Demonstration of the Lillie Iron Wire Nerve Conduction Model" by R. L. Taylor, M.S., D. R. Turner, Ph.D., and H. M. Straube, B.S.E.E., Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Theoretical Electrochemistry

Monday, April 13, 1953
General Theoretical Session
Walter J. Hamer presiding

2:00 P.M.—"Kinetics of Layer Formation on Copper Anodes in HCl and KCl Solutions" by J. H. Bartlett and Lee Stephenson, Department of Physics, University of Illinois, Urbana, Ill.

2:25 P.M.—"An Optical Method (Schlieren) for the Quantitative Investigation of Diffusion Layers" by Lee Stephenson, Department of Physics, University of Illinois, Urbana, Ill.

2:50 P.M.—"Electrochemical Polarization of Zirconium in Sodium Chloride Solution" by Norman Hackerman and Olin B. Cecil, Department of Chemistry, University of Texas, Austin, Texas.

3:15 P.M.—"Structural Features of Oxide Coatings on Aluminum" by F. Keller, M. S. Hunter, and D. L. Robinson, Aluminum Research Laboratories, Aluminum Company of America, New Kensington, Pa.

3:40 P.M.—"Experimental Study of 'Potential-*p*H-Rate of Corrosion' Diagrams" by Paul Delahay, George L. Stiehl, John A. Perry, and Talivaldis Berzins, Department of Chemistry, Louisiana State University, Baton Rouge, La.

4:10 P.M.—"Electrolysis at Constant Current" by Paul Delahay and

Talivaldis Berzins, Department of Chemistry, Louisiana State University, Baton Rouge, La.

Thursday, April 16, 1953
Theoretical Electrochemistry (cont'd.)
General Theoretical Session
Walter J. Hamer presiding

9:00 A.M.—"The Acid Dissociation of the Aquoscandium Ions, II. Effect of Temperature and of Ionic Strength" by Martin Kilpatrick and Lewis Pokras, Department of Chemistry, Illinois Institute of Technology, Technology Center, Chicago, Ill.

9:25 A.M.—"Cation Exchange Process for the Preparation of Potassium Cyanide" by C. H. Lemke, Research Division, Electrochemicals Department, E. I. du Pont de Nemours & Company, Inc., Niagara Falls, N. Y.

9:50 A.M.—"The Preparation and Electrochemical Properties of Iron and Cobalt Phosphides" by Donald W. Wood, Standard Oil Development Company, Esso Research Center, Development Division, Linden, N. J., and John C. Bailar, Jr., Herbert A. Laitinen, and Sherlock Swann, Jr., Department of Chemistry, University of Illinois, Urbana, Ill.

10:15 A.M.—"Equivalent-Circuit Model of the Transference Cell" by George W. Murphy, Argonne National Laboratory, Lemont, Ill.

10:40 A.M.—"Current Distribution over Electrodes of Finite Conductivity" by Charles W. Tobias, Department of Chemistry and Chemical Engineering, and Robert A. Wijsman, Department of Physics, University of California, Berkeley, Calif.

11:05 A.M.—"Polarization Measurements with the Oxygen Electrode" by R. R. Witherspoon, Ernest Yeager, Herman Urbach, and Frank Hovorka, Department of Chemistry, Western Reserve University, Cleveland, Ohio.

11:30 A.M.—"Ionic Vibration Potentials" by Ernest Yeager, Harry Dietrick, Frank Saunders, and Frank Hovorka, Department of Chemistry, Western Reserve University, Cleveland, Ohio.

2:00 P.M.—"On the Electrochemistry of Ion-Exchange Resins" by K. S. Spiegler, Department of Chemistry and Laboratory for Nuclear Science and Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

2:25 P.M.—"Apparatus for Studying Electrogravitational Separations. Some Experiments on the Extraction of Sodium Chloride from Solution in a Flow System" by George W. Murphy and David Batzer, Department of Chemistry, University of Wisconsin, Madison, Wis.

2:50 P.M.—"Stabilization of the Divalent State of Silver Through Coordination" by A. L. McClelland, Department of Chemistry, University of Connecticut, Storrs, Conn., and J. C. Bailar, Jr., and H. A. Laitinen, Department of Chemistry, University of Illinois, Urbana, Ill.

3:15 P.M.—"Rate of Displacement of Silver from Aqueous Solutions of Silver Nitrate by Zinc and Copper" by Richard Glicksman, Henri Mouquin, and Cecil V. King, Department of Chemistry, Washington Square College, New York University, New York, N. Y.

3:40 P.M.—"Effect of Stress on Metal Electrode Potentials" by Robert E. Fryxell and Norman H. Nachtrieb, Institute for the Study of Metals, University of Chicago, Chicago, Ill.

4:05 P.M.—"Electrochemical Properties of Dilute Sodium Amalgams" by Harry Dietrick, Ernest Yeager, and Frank Hovorka, Department of Chemistry, Western Reserve University, Cleveland, Ohio.

Abstracts Booklet for Electronics Division

The Electronics Division will again publish an "Enlarged Abstracts" booklet for the 1953 Spring Meeting of the Society at New York. The booklet will have 1000-word abstracts of each paper to be given at the sessions of the Electronics Division in their symposia on *Luminescence*, *Phosphor Screen Application*, *Rare Metals* and *Semiconductors*.

The abstracts will contain pertinent information and experimental data given in the papers and will provide these details before publication, thus aiding workers in the field. The abstracts will be "printed but not published."

The abstract booklets are expected to be available by March 15th; the price will be about $1.50. Orders should be sent to C. W. Jerome, Sylvania Electric Products Inc., 60 Boston Street, Salem, Massachusetts.

Sarkes Tarzian, Rectifier Division, New Sustainer

Among the companies which have recently become sustaining members of The Electrochemical Society is the Rectifier Division of Sarkes Tarzian, Incorporated, Bloomington, Indiana.

The Rectifier Division of Sarkes Tarzian was started in October, 1949, to manufacture radio-type selenium rectifiers. They were used to power radio and television sets and small electronic devices. The business grew at quite a rapid pace and requests were received from many customers to manufacture commercial type rectifiers such as those used in battery chargers, electroplating power supplies, and thousands of other devices.

Today the Division is one of the world's largest manufacturers of all types of selenium rectifiers, and one of the world's largest users of high-purity selenium. They are servicing approximately six thousand electronic manufacturers and many of the military services throughout the United States and the rest of the world. In addition, they have a research department with all the necessary equipment to do research on other elements they might use to manufacture dry disk rectifiers, other than selenium. The staff consists of six chemical engineers and 25 electrical engineers besides approximately four hundred people in the factory.

Correction

In the article "Nature of the Films Formed by Passivation of Iron with Solutions of Sodium Phosphate" by M. J. Pryor, F. Brown, and Morris Cohen, which appeared on page 542 of the December 1952 JOURNAL, footnote 2 is in error and does not belong to this paper.

ABC Questionnaires Wanted Promptly!

All Society members and subscribers have been sent a request for their job categories in terms needed by the Audit Bureau of Circulations (ABC) for a classification of *Journal* readers, relative to advertising. *It is very important that everyone return his questionnaire promptly.* If you have not already returned it, will you kindly do so immediately.

The Electrochemical Society, Inc., 235 West 102nd Street, New York 25, N. Y.

R. M. Burns and Scott Ewing Receive 1953 Whitney and Speller Awards

R. M. Burns

Scott P. Ewing

The 1953 Whitney and Speller Awards, sponsored by the National Association of Corrosion Engineers for outstanding achievement in corrosion technology, were presented this year to Robert M. Burns and Scott P. Ewing, respectively.

R. M. Burns, Chemical Coordinator and Director of Chemical and Metallurgical Research for Bell Telephone Laboratories, Murray Hill, New Jersey, was selected to receive the Willis Rodney Whitney Award in recognition for achievement in corrosion science. Scott P. Ewing, corrosion engineer for the Carter Oil Company, Tulsa, Oklahoma, was the recipient of the Frank Newman Speller Award, given for achievement in the field of corrosion engineering. The presentation of the certificates of award was made at the annual banquet of the association, held on March 19, at the Hotel Sherman, Chicago, during the Ninth Annual Conference and Exhibit.

The awards were established by NACE in 1947, the Whitney Award being first conferred on Willis Rodney Whitney, for whom it was named. The Speller Award was named for Frank Newman Speller, the first to receive the honor.

Dr. Burns, recipient of the Whitney Award, has been honored frequently for his contributions to science—and by election to many offices and posts of responsibility in the organizations to which he belongs. He has published numerous articles in the field of corrosion and is senior author of the book "Protective Coatings of Metals."

Currently, he is Chairman of the Publication Committee of The Electrochemical Society and editor of the Society's Journal. Previously, he has been treasurer, secretary, and president of the Society.

A graduate of the University of Colorado, he later received the honorary degree of Doctor of Science from that institution; his Ph.D. degree was granted at Princeton. In addition to membership in various university fraternities, he has been national president of Alpha Chi Sigma, the professional chemical fraternity. In 1952 he was awarded the Perkin Medal, considered the highest award for achievement in American chemical industry.

Aside from his work at Bell Laboratories, which he joined in 1925, Dr. Burns has been one of the leading sponsors of cooperative effort in assembling the work and data of many organizations on corrosion. He was one of the organizers and, later, chairman of the American Coordinating Committee on Corrosion, and was chairman for the first two years of the A.A.A.S. Conference on Corrosion at Gibson Island. He served as consultant on numerous advisory committees for the NDRC, the National Research Council, and for the Armed Services. Dr. Burns also acted as adviser in the preparation of the "Corrosion Handbook," sponsored by The Electrochemical Society.

Dr. Ewing, who received the Speller Award, is an outstanding authority on underground and marine corrosion problems in which he has been engaged for the past 30 years. His present work at the Carter Oil Company laboratory is concerned with the prevention of corrosion in oil refineries and oil production equipment.

Born in Smithfield, Utah, Dr. Ewing was granted a B.S. degree at Utah State Agricultural College in 1920 and a Ph.D. degree in physics at the University of California in 1925.

After a year as physics instructor at Lehigh University and a year at the National Bureau of Standards, he remained at the Bureau from 1928 to 1940 as Research Associate for the American Gas Association. His principal interest at this time was pipe coatings and soil corrosion; his book, "Soil Corrosion and Pipe Line Protection," was published in 1938.

In 1940 Dr. Ewing went to the Canal Zone where he worked with Dr. F. N. Speller on an Army project concerned with the cathodic protection of the locks and gates of the Panama Canal. As a result of this work all of the locks and some of the other canal structures are now cathodically protected. During World War II he was employed by the Navy Department, Bureau of Ships, where he was engaged on a number of naval corrosion problems. Previous to joining the Carter Oil Company in 1947, Dr. Ewing undertook a short-time project at Lake Maracaibo, Venezuela, for the protection of pipelines carrying petroleum and petroleum products.

Notes from India

New Caustic Soda Plant at Alwaye

An important step in the industrial development of India was taken with the opening, in December 1952, of the new caustic soda plant of Travancore-Cochin Chemicals Ltd., at Alwaye. This is a new combine of which the participants are the Travancore-Cochin State Government, Fertilisers & Chemicals (Travancore) Ltd., and the Mettur Chemical and Industrial Corporation Ltd., Mettur Dam. The mercury cell plant, the biggest single unit in the country, has a capacity of 20 tons per day of high purity caustic soda which will meet the requirements of the rayon industry. With full production, the plant is expected to save India a sum of Rs.35 lakhs ($700,000.00).

Notes from India (cont'd.)

Monazite Factory in India

The Prime Minister of India opened the Indian Rare Earths Ltd., at Alwaye in December 1952. This factory processes the monazite sands, deposited in large quantities along the coasts of the Travancore-Cochin State, into thorium and other valuable products. It is one of the many undertakings of the Government of India to develop the natural resources of the country. The factory has been designed to process 1,500 tons of monazite annually, with capacity for doubling the output.

Central Electrochemical Research Institute at Karaikudi

The Central Electrochemical Research Institute was officially opened by the Vice-President of India in January 1953. It is the ninth in the chain of National Laboratories set up in India by the Council of Scientific and Industrial Research. The Institute is located on a 300-acre estate donated by Dr. Alagappa Chettiar (a Patron of the India Section) who has also given Rs.15 lakhs ($300,000.00) toward its establishment. There will be 5 divisions for carrying out the work of the Institute: Electrometallurgy and Electric-furnace products, Electrolytic cells, Electrodeposition and Allied Processes, Electrochemistry of gases, Research Utilization, and Information. The main functions include (1) basic or fundamental research, (2) research of an applied nature with a view to increasing the productive capacity and efficiency of existing industries, (3) investigations leading to and including pilot plant trials, (4) liaison with work in allied fields in research institutes, universities, and industrial establishments, (5) testing and standardization of raw materials and finished products, and specifications for raw materials and finished products, (6) collection of data and technical information and dissemination of the same, (7) training of technologists, (8) organization and maintenance of an industrial museum for the display of new products, process charts, and other materials of interest to the electrochemical industry.

At the opening ceremony, Dr. B. B. Dey was named Director, and Dr. B. K. Ram Prasad, First Chairman of the India Section and at present Chairman of the *Bulletin* Editorial Committee of the India Section, was named Associate Director.

T. L. R. C.

SECTION NEWS

Detroit Section

A joint dinner meeting of the Detroit Sections of The Electrochemical Society and the National Association of Corrosion Engineers took place on February 19 at the Banquet Hall of the Detroit Engineering Society.

The guest speaker for the occasion was Mars G. Fontana, Supervisor of Metallurgical Research, Ohio State University. Dr. Fontana is well known in both societies for his many activities and, currently, is president of NACE. He is an authority on corrosion, having published outstanding books and articles on the subject, and he also holds a number of patents in this field. He presented an able discussion on "Corrosion and Its Prevention," which was well received by the large audience attending.

G. V. Kingsley, *Secretary-Treasurer*

Chicago Section

A "University Night," held by the Chicago Section at its January 9th meeting, proved to be a most informative and pleasurable evening. Following a cocktail hour and dinner, the gathering heard speakers from three universities on the subjects noted below:

1. Donald D. DeFord, Assistant Professor of Chemistry, Northwestern University, "Coulometric Titrations."
2. Norman H. Nachtrieb, Associate Professor of Chemistry, University of Chicago, Institute for the Study of Metals, "Polarography in Fused Salts."
3. Matthew C. Urbin, Department of Biochemistry, Graduate School and Stritch School of Medicine, Loyola University, "Ionography: The Fundamentals and Some Applications."

1. Dr. DeFord discussed recent work in his laboratory employing the principle of *electrolytic* production of a titrating reagent, measured by the *current and time* used to produce it. Thus, it is possible to carry out *microtitrations* of the acid-base or oxidation-reduction types with far greater precision than would be possible with volumetric methods.

2. Dr. Nachtrieb summarized his experiments with low melting salts in polarographic studies. Dropping mercury electrodes function in such media in a manner quite similar to their behavior in aqueous systems. When molten lead was substituted for mercury (in higher melting salts), unsatisfactory dropping characteristics were found and polarographic studies were unsuccessful.

3. Mr. Urbin presented a most interesting account of his current graduate work in "ionography," which is an intriguing combination of electrophoresis and paper chromatography. Thin lines of colloidal suspensions or electrolytes are applied crosswise on a long, wet, paper strip. Application of voltage to the ends of the strip causes migration and separation of the charged constituents. The technique has been successfully applied to amino acid preparations and physiological fluids, as well as to other materials.

R. R. Banks, *Secretary*

Niagara Falls Section

On February 17 the Niagara Falls Section held a joint meeting with the Western New York Section of the American Chemical Society. This is a continuance of a tradition which was first established in 1944, with the speakers provided by the Niagara Falls Section of The Electrochemical Society. Sixty-one members and guests were present for dinner and two hundred for the talk following.

Leonard W. Niedrach

The speaker was Dr. Leonard W. Niedrach, of the Knolls Atomic Power Laboratory, General Electric Company, Schenectady, New York, who addressed the members of the two societies on the subject "Atomic Power: Present and Future." A summary of Dr. Niedrach's address follows.

The present status of atomic power can be summarized by stating that it is feasible technically today. If a power reactor economy were based upon the current high military value of plutonium, it is possible that atomic power from power-converter or better, power-

breeder, reactors could now compete economically with coal stations. It is not likely, however, that a widespread use of atomic power will come about until competition with coal becomes real on the basis of the fuel values of plutonium.

We are therefore now in the transition period between technically feasible and economically feasible power. During this period when the necessary basic research will be performed, only the government can be expected to carry the major load of the development program. It is likely that during this period a few power reactors will be built to obtain fundamental design data for future improvements.

By thorough cooperation among reactor engineers, metallurgists, physicists, and process chemists, the construction and operating costs of reactors may ultimately be reduced to the point where they are feasible economically as power sources. Some of the areas for possible cost reduction in atomic power plants are simplified construction, simplified reprocessing, and increased fuel burn up per cycle through the reactor. It is possible that all of these improvements may be accomplished simultaneously through the use of fluid fuel—homogeneous reactors.

In addition to aiming at reducing the basic costs of reactors, some effort is also being made to increase the subsidization of reactors through the sale of by-products. In this direction improved yield of the valuable by-product, plutonium, is being sought. Work is also progressing on the development of new methods of utilization of fission products. There are, for example, indications of possible uses in food sterilization, the pharmaceutical industry, industrial radiography, and as a source of energy for new types of synthesis reactions.

MILTON JANES, *Secretary-Treasurer*

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Washington-Baltimore Section

Dr. Samuel Eidensohn of the Bureau of Ships, Washington, D. C., addressed the Washington-Baltimore Section, at its February 19th meeting, on the subject "Electrochemical Sources of Power."

After defining an electrochemical source of power as an arrangement of reactants whereby the free energy of the reaction is converted directly into electrical energy, it was pointed out that over 150 years ago, it was realized that if carbon could be used as the anodic reactant in such an arrangement, theoretical efficiencies approximating 100 per cent could be obtained. A cell in which carbon is oxidized electrochemically to CO_2 could, theoretically, have an emf of slightly over one volt and an efficiency of over 99 per cent. This, of course, disregards the fact that the oxygen electrode in its usual form shows appreciable losses, and also disregards the ohmic loss. Another expression of the possible advantage of the carbon cell over the heat engine-generator is that the carbon consumed per kwhr would be 0.25 pound for the cell as compared with 1.0 pound for the heat engine-generator set. Theoretical emf and efficiencies for the reactions $C + O_2 \rightleftharpoons CO_2$, $2C + O_2 \rightleftharpoons 2CO$, $2CO + O_2 \rightleftharpoons 2CO_2$, and $2H_2 + O_2 \rightleftharpoons 2H_2O$, calculated by a Russian, Davtyan, in a a review published in 1947 were presented for the range 25°–3727° C. Additional data by McKee and Adams, and Ellingham were also presented.

These theoretical possibilities have not been realized in experimental work. The direct anodic oxidation of carbon has shown little promise. Recent experiments by the British Coal Utilization Research Association on cells of the Baur type using Carbon Solid Electrolytic Conductor $(O_2)Fe_2O_3$, Fe_3O_4 operating at 1150°–1200°C, gave an efficiency of only 2 per cent based on

the combustion of carbon to CO_2. Only 8.5 watts per square foot of electrode were obtained. At this temperature, the protection of carbon against direct attack is very difficult and at lower temperatures the output power is reduced. A cell built by Bischoff (1951) using fused sodium carbonate electrolyte, operating at 700°C, gave only 0.3 watt per square foot.

Higher output has been obtained by using carbon indirectly. The best anodic material appears to be hydrogen which can be generated by reacting carbon with steam. Russian work on hydrogen-air and hydrogen-oxygen cells is reported by Davtyan to give about 25 watts per square foot at room temperature. Much higher results have been reported by an English investigator, Bacon, using conditions of 200°C and 600 psi. He reports 600 amperes per square foot at 0.6 volt, for pure hydrogen and pure oxygen. However, the Bacon cell has an operating life of only a few hours at maximum output. This is caused by the oxidation of the positive electrode material (nickel).

The British effort has been based on the idea of using irregular wind power to generate electric power which is used to electrolyze water into hydrogen and oxygen. The energy is to be stored in the separate gases and obtained electrically by feeding the gases into electric cells. This is a departure from the classic fuel cell concept and represents an attempt to use irregular natural energy sources on a storage basis. If the life problem can be solved, the Bacon cell may take its place with the more familiar "package" cells as an electrochemical source of power.

The talk was very well received and created a lot of interest, as evidenced by the discussion which followed.

At a previous meeting of the Section, held on December 18, Harold Berzof, Technical Advisor, U. S. Air Force, spoke on the topic "Dielectric Studies in Non-Polar Polymers."

FIELDING OGBURN, *Secretary*

Change of Address

The Universal Oil Products Company has moved from 2120–310 S. Michigan Ave., Chicago, to 30 Algonquin Rd., Des Plaines, Ill. All departments are now located at the new address except the research laboratories which are still at Riverside, Ill.

The McGraw-Hill News Bureau has moved from 566 Merchants & Manufacturers Building, 1 Main St., to 1303 Prudential Building, Houston 25, Texas.

DIVISION NEWS

Electronics Division

The annual business meeting of the Electronics Division will be held on Tuesday, April 14, at 12:30 P.M., during the Spring Meeting of the Society, in New York.

Changes in Bylaws

At the Executive Committee meeting of the Division in Philadelphia in 1952, the following changes in our bylaws were proposed:

1. In Article 1, Section 2, and Article 7, Section 2, replace "Fluorescence" with "Luminescence." (This was an error in the original bylaws which is being corrected.)

2. Article 2, add: "Section 3.—Fiscal Year. The fiscal year of the Division shall be from June 1st to May 31st." (Inserted at the request of the Society; we previously had no official fiscal year.)

3. Article 6, Section 1, add "The most recent past Division chairman and the chairmen of symposia shall also be on the executive committee. No member of the executive committee may have more than one vote." (The past Division chairman is included to allow continuity of action. Symposia chairmen are added to better plan their symposia. The "one-vote" addition is made to include a provision implicitly planned when the bylaws were drawn up.)

These changes will be voted on at the business meeting.

* * *

The Nominating Committee, H. C. Froelich, Chairman, S. Jones, and D. M. Wroughton, have selected the following nominees for office during the 1953–54 term:

General Chairman—R. H. Cherry, Leeds and Northrup Company, Philadelphia, Pa.

Group Chairman (Rare Metals)—A. U. Seybolt, Research Laboratory, General Electric Company, Schenectady, N. Y.

Group Chairman (Luminescence)—J. H. Schulman, Crystal Branch, Naval Research Laboratory, Washington, D. C.

Group Chairman (General Electronics)—A. E. Hardy, R. C. A. Victor Division, Lancaster, Pa.

The term of the Secretary-Treasurer, C. W. Jerome, has two more years to run. All nominees have given assurance of their willingness to serve.

The bylaws of the Division provide that additional nominations may be made by petition signed by 5 members of the Division. Such petitions must be in the hands of the Nominating Committee Chairman before the election and the nominees must give assurance of their willingness to serve.

The election will be held at the business meeting of the Division.

C. W. JEROME, *Secretary-Treasurer*

PERSONALS

H. C. SCHLAUPITZ, research engineer for R. Wallace & Sons Manufacturing Company, Wallingford, Connecticut, has been named Director of Research for the company.

A. H. ANDERSEN, Shawinigan Chemicals Ltd., Shawinigan Falls, Canada, is now located at the company's office in Montreal.

CYRIL S. TAYLOR, Aluminum Research Laboratories, New Kensington, Pennsylvania, has retired from active service and is now residing at Chinook, Washington.

N. SUBRAHMANYAN, formerly chemist at the Mettur Chemical and Industrial Corporation, Mettur Dam, has joined the Central Electrochemical Research Institute, Karaikudi, as senior scientific assistant.

MILTON JANES has transferred from the National Carbon Company Process Engineering Laboratory at Niagara Falls, New York, to National Carbon Research Laboratories, Cleveland, Ohio.

WILDER D. BANCROFT

Dr. Wilder D. Bancroft, one of the founders of The Electrochemical Society and twice its president, in 1905 and 1919, died at his home in Ithaca, New York, on February 7, at the age of 83. He had been professor of chemistry at Cornell University from 1903 until his retirement in 1937.

Dr. Bancroft was a pioneer researcher into the application of colloid chemistry to the human body and he won the William H. Nichols Medal of the American Chemical Society in 1933 for his achievements in this field.

He was born in Middletown, Rhode Island, and graduated from Harvard University in 1888, continuing graduate work at Harvard and four years of special work at Strassburg, Leipzig, Berlin, and Amsterdam. He received

the Ph.D degree from the University of Leipzig and honorary doctor of science degrees from the Universities of Lafayette and Cambridge, in addition to a number of other honorary memberships and awards.

Dr. Bancroft founded the *Journal of Physical Chemistry* in 1896 and edited it until 1932. Also, during his active career, he was a consulting chemist of the Federal Bureau of Mines, a fellow of the American Academy of Arts and Sciences, president of the American Chemical Society, and of the American Physical Society; he was a member of the American Electroplaters' Society, the National Academy of Science, and the American Philosophical Society.

OLIVER P. WATTS

Oliver Patterson Watts, 87, dean of professors of applied electrochemistry in this country, died on February 6 at his home in Madison, Wisconsin.

Dr. Watts was born in Thomaston, Maine, in 1865, and graduated from Bowdoin College in 1889. Following graduate work at Clarke University, Worcester, Massachusetts, and early teaching which included six years of chemistry and physics, Dr. Watts became interested in the great developments in applied electrochemistry then receiving attention.

He studied electrochemistry at the University of Wisconsin and received his doctorate degree there in 1905. He remained as instructor and professor until his retirement in 1937. He received, in 1924, the honorary degree of Doctor of Science from his alma mater, Bowdoin College.

Dr. Watts' scientific writings, of which 31 appeared in the TRANSACTIONS of this Society, include the general theories and applications of electrochemistry, corrosion studies, the behavior of voltaic couples, electroplating problems, and investigations in metallurgy. He developed the hot nickel plating bath, known throughout the world as the "Watts Bath."

He joined The Electrochemical Society in 1904 and served as its vice-president in 1927–28.

NEW MEMBERS

In February 1953, the following were elected to membership in The Electrochemical Society:

Active Members

PHILIP F. ALBERT, Ray-O-Vac Company, mailing add: 301 N. Owen Dr., Madison 5, Wisconsin (Battery)

CHARLES O. BADGETT, Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa. (Electronics, Electro-Organic, and Theoretical Electrochemistry)

STANLEY W. BUBRISKI, Sprague Electric Company, mailing add: The Knolls, Williamstown, Mass. (Electronics)

LESLIE A. DOGGRELL, Hart Battery Division, Dominion Linseed Oil Company, Ltd., St. Johns, P.Q., Canada (Battery)

GEROULD GADSDEN, International Minerals & Chemical Corporation, P.O. Box 866, Niagara Falls, N. Y. (Corrosion and Industrial Electrolytic)

DAVID L. HAWKE, National Lead Company, mailing add: 7153 Amboy Rd., Tottenville, Staten Island, N. Y. (Battery and Corrosion)

BURTON B. KNAPP, International Nickel Company, Inc., Bayonne, N. J. (Corrosion and Electrodeposition)

ZENON V. KOSOWSKI, Crane Company, Engineering Laboratory, 836 S. Michigan Ave., Chicago, Ill. (Corrosion)

JAMES R. MCCAUGHNA, Penta Laboratories, Inc., mailing add: P.O. Box 301, Santa Barbara, Calif. (Electrodeposition)

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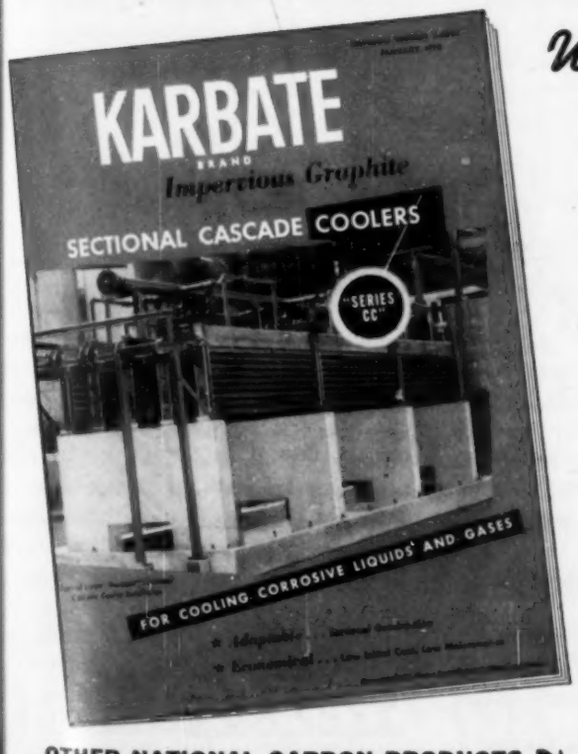

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ucts & Chemical Corporation, 4800 S. Central Ave., Chattanooga, Tenn. (Electrothermic)

FRED E. OLMSTEAD, Packard Motor Car Company, 1580 E. Grand Blvd., Detroit, Mich. (Electrodeposition)

JOSEPH PARKER, Diamond Alkali Company, mailing add: 298 W. Washington Ave., Painesville, Ohio (Industrial Electrolytic)

NORMAN L. PIEGOLS, Dow Chemical Company, mailing add: Route #2, Freeland, Mich. (Industrial Electrolytic)

PRESTON ROBINSON, Sprague Electric Company, North Adams, Mass.

EDWARD B. SAURESTRE, Sylvania Electric Products Inc., mailing add: 80-15 57 Ave., Elmhurst, N. Y. (Corrosion and Electrodeposition) Formerly Student Associate Member

RALPH P. SEWARD, The Pennsylvania State College, mailing add: 720 Thomas St., State College, Pa. (Theoretical Electrochemistry)

CARL E. VAN WINCKEL, The Carwin Company, North Haven, Conn. (Electro-Organic)

PRENTISS S. VILES, Humble Oil and Refining Company, mailing add: 611 West Jack St., Baytown, Texas (Corrosion)

ALVIN G. WINGER, Rohm & Haas Company, mailing add: 1424 Princeton Ave., Philadelphia, Pa. (Theoretical Electrochemistry)

Associate Members

KENNETH A. KUN, U. S. Electric Manufacturing Company, mailing add: 1666 Brooklyn Ave., Brooklyn, N. Y. (Battery)

MILLER H. PETERSON, Naval Ordnance Laboratory, mailing add: 2003 Fordham St., Apt. 104, Hyattsville, Md. (Battery)

NORMAN P. SWEENY, The Dow Chemical Company, mailing add: 501 State St., Midland, Mich. (Industrial Electrolytic)

Student Associate Members

EDWARD HILLNER, New York University, mailing add: 1175 Morris Ave., Bronx, N. Y. (Corrosion)

PETER F. KING, Room 8-204, Massachusetts Institute of Technology, Cambridge, Mass. (Corrosion)

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LETTERS TO THE EDITOR

Iron Passivation in Nitric Acid

Dear Sir:

Gatos and Uhlig, in their paper "Passivity of Iron in Nitric Acid,"[1] describe a series of experiments to measure the thickness of the layer removed from an iron film in the process of passivation in concentrated nitric acid. For an untreated film, the layer is 2200 Å thick.

I have been investigating some of the properties of passive iron as part of a study of the Lillie iron-wire nerve model.[2] One of the tests corroborates the findings of Gatos and Uhlig.

In this test, an iron wire, 10 cm long, and 0.3 cm in diameter, is suspended horizontally in the acid. It is normally passive, but is triggered into activity by a short pulse of electric current. The pulse is obtained by charging a capacitor with a battery, and discharging it through a platinum triggering electrode placed near the wire (Fig. 1). The switching is done by a timer-driven cam operating a microswitch, so that pulses are applied at fixed intervals (20 sec to 1 min). With each pulse a wave of activity travels down the wire, after which it again becomes passive. In this manner a single wire may be subjected to many hundred activation cycles, so that the average effect per cycle may be obtained by measuring the diameter with a micrometer calipers.

It is found that in a very few cycles, the wire loses its smooth drawn finish, and obtains the characteristic silvery cratered surface of passive iron. After this, the thickness of iron removed per cycle remains fairly constant. The results of averaging many trials are given in Table I. The acid bath used for these tests was 13*N* HNO_3. This acid had been used repeatedly and was well contaminated with ferric ion and many other reaction products. It is noted that the portion of the wire close to the trigger electrode shows much more reaction per cycle, since some iron is removed faradaically by the trigger pulse. This pulse is quite large, 2000 mf at 45 volts, or .09 coulombs, and is necessitated by the short repetition time used. At the end of 20 seconds the wire is still refractory and needs a large trigger to be activated.

TABLE I

Wire	Carbon %	Layer removed per cycle - Å	
		Near trigger probe	Far from trigger probe
Armco Iron	.012	3300	2500 — 10% + 2%
Soft CRS	.20	3000	2700
Drill Rod	1.00	—	>2000

The layer of iron removed per cycle, 2500 Å, agrees with the data of Gatos and Uhlig. It is interesting to note that soft cold-rolled steel of much higher carbon content gives similar results. The same process was tried with a sample of drill rod (1% carbon steel). This could only be run for about 50 cycles before it would no longer activate. Apparently the iron would dissolve in the process leaving a coating of very fine carbon or carbide on the surface. This residue has a strong inhibiting effect on the activation process. From what data could be obtained, the reaction layer thickness seems to be the same as with the other iron.

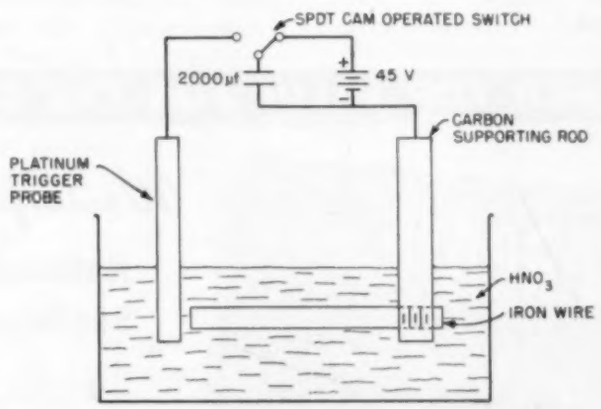

FIG. 1. Repeated activity cycling of passive iron wire.

SAUL ARONOW
Harvard University
Cambridge, Massachusetts

[1] H. H. UHLIG AND H. C. GATOS, *J. Electrochem. Soc.*, **99**, 250 (1952).

[2] O. GLASSER, "Medical Physics," p. 79, Yearbook Publishers, Chicago (1944).

Letters to the Editor (cont'd.)

Electrochemistry in South America

Dear Sir:

I remember once writing to you in appreciation of an editorial you had written, and your response that you were glad to know that your editorials were read gives me courage to write again to say that I approve heartily of the decision of the Editors, expressed in your editorial on page 3C [January 1953, JOURNAL] to publicize electrochemical work in foreign lands.

In the spring of 1951 I had the opportunity of traveling and lecturing in Peru, Chile, Argentina, and Brazil where I could see the need of encouraging scientific work in those countries. The chemists of South America strongly desire North American journals, visits to this country, and visits of North Americans to their countries so that they can learn of the latest scientific developments in our great country.

Professor Ridriguez Réguli of Montevideo, Uruguay, mentioned to me particularly his interest in the JOURNAL of The Electrochemical Society. For the most part, however, the South American scientists take no North American journals, and for this reason are avid for any kind of scientific news. Anything that The Electrochemical Society could do to promote the exchange of journals would be greatly appreciated and would be most worthwhile in South America.

MALCOLM DOLE
Northwestern University,
University of Illinois

BOOK REVIEWS

AN INTRODUCTION TO THE CHEMISTRY OF THE HYDRIDES by Dallas T. Hurd. Published by John Wiley and Sons, Inc., New York, 1952. 231 pages, $5.50.

This book offers a convenient and concise review of the chemistry of the hydrides. In it, all binary compounds, resulting from combination of hydrogen with the elements, are grouped into three main categories: ionic hydrides, covalent hydrides, and the transitional metal hydrides. A brief but thorough description of the current theories on chemical bonding and structure of the hydrides is presented at the outset. After a short introduction, the hydrides of the alkali and alkaline earth metals are treated in succession. For lithium hydride—a typical example—the physical properties, structure, preparation, reactions, precautions in handling, and uses are all covered, followed by selected literature references.

In the section on covalent hydrides, boron is justifiably discussed in considerable detail. Evolution of bond theory in boron hydrides is outlined starting with the "no-electron" and "one-electron bond" and culminating with the current "protonated double bond" and "half bond" proposals. Fascinating coordination compounds and derivatives, such as borine carbonyl and borazole are mentioned.

Of special interest to electrochemists is the chapter on transitional metal hydrides. Although they are not real compounds in the usual sense, these hydrides do exhibit systematic differences.

Other features are a chapter on hydride nomenclature and appropriate appendixes on deuterides, hydride toxicology and recommended commercial sources of hydrides.

F. H. WINSLOW

PHASE RULE, Ninth edition, by Alexander Findlay, revised by A. N. Campbell and N. O. Smith. Published by Dover Publications, Inc., New York, 1951. xii + 494 pages, $1.90 paper bound, $5.00 cloth bound.

The ninth edition of "Phase Rule," like its predecessors, is written without recourse to thermodynamics as a structure upon which to develop the subject. This limitation leads to difficulties such as the necessity of a less-than-convincing justification argument in setting down the phase rule, the introduction on faith of Rauolt's law, and equations such as those of Clausius and Van't Hoff (for freezing point lowering). Rejecting the mathematical framework of thermodynamics makes description of the unwieldy material of phase equilibria extremely difficult; in spite of this, the authors' presentation is orderly and not overly verbose.

Approximately one half of the new ninth edition, including the excellent chapter on dynamic isomerides, is taken virtually unchanged from the preceding edition. Four chapters, three on two component systems describing freezing-point curves, systems of solid and gas phases only, and co-existence of solid, liquid, and gas phases and one chapter on four component aqueous electrolyte systems, have been rewritten in part, the principal change being in order of presentation. Three chapters, those describing two- and three-component systems of solid and liquid phases only and one describing three-component aqueous systems, have been almost entirely rewritten. Two excellent chapters describing liquid-vapor systems of two and three components and the relation of the phase rule to distillation have been added. A short chapter on multiple component systems has been added by discussing sea water as a five- and six-component system rather than one of four components as done in the eighth edition. A short section qualitatively relating phase diagrams to free-energy diagrams has been added as an appendix. Some of the material on experimental determination of binary solid-liquid equilibria deleted from the text has been added as an appendix.

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In addition to presenting some new experimental data, revision and addition has been such as to present the subject in rigid accordance with the classification system of the phase rule. Methods of graphical representation of data have been emphasized at the expense of historical notes and, also, some experimental results not well classified according to the phase rule (such as hydrogen absorption by palladium); this makes the ninth edition a more orderly text but less interesting reading than its predecessor. Extensive appendixes providing a rigorous thermodynamic framework and a thorough discussion of the estimation of activities from phase diagrams would make this valuable book indispensable.

J. L. LUNDBERG

RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

November 25, 1952

Butler, K. H., 2,619,471, Calcium Phosphate Phosphors

Schoenfeldt, H. R., 2,619,472, Fluorescent Coating Method

Briggs, R. L. Jr., 2,619,624, Method for Reconditioning and Charging Batteries

December 2, 1952

Bramley, J., 2,620,287, Secondary-Electron-Emitting Surface

Wilsdon, S. C., 2,620,296, Method of Electrolytically Coating and Etching Bearing Surfaces

Stobie, J. J., and Youngkrantz, H. R., 2,620,297, Anode Structure

Fischer, K. A., 2,620,298, Apparatus for Electrically Filtering Paraffins

Ladell, E., 2,620,366, Induction Stirrer

Brown, H. G., 2,620,367, Lead-Acid Accumulator

Ruben, S., 2,620,368, Alkaline Dry Cell

Daniel, A. F., 2,620,369, Plastic-Cased Dry Cells

Chapman, E. S., 2,620,370, Electrical Storage Battery

Bowditch, F. T., 2,620,371, Pocket for Immobilizing Inert Gas in Battery Cathodes

Tarzian, S., 2,620,384, Selenium and Like Rectifier Stack

December 9, 1952

Loveless, D. L., 2,621,119, Stainless Steel Melting Process

Gresham, H. E., Wheeler, M. A., and Hall, D. W., 2,621,122, Alloy for Heat and Corrosion Resisting Coating

Hoffman, R. A., 2,621,152, Zinc Cyanide Plating Bath

Meyer, R. H. M., and van der Plas, F. J. F., 2,621,153, Preparation of Trichloroethane

Mears, R. B., 2,621,154, Packaged Electrodes for the Cathodic Protection of Metallic Underground Structures

Williams, H. B., 2,621,155, Cathode Structure

Juckniess, P. R., 2,621,218, Electric Graphitizing Furnace

Winkel, H. C., 2,621,219, Battery Grid

Kirk, R. C., Fry, A. B., and George, P. F., 2,621,220, Primary Cell

deMunck, Y., 2,621,221, Trough for Battery Accumulators

Wirth, G. S., 2,621,222, Battery Terminal Connector

Jewell, R. L., 2,621,235, Draw-Off Cock and Temperature Compensated Conductivity Cell for Distilled Water

December 16, 1952

Angel, E. G. R., 2,622,063, Electrolytic Production of Iron and Iron Alloys

Maize, J. A., 2,622,116, Thermoelectric Device

Benzer, S., 2,622,117, Photovoltaic Device

Knasko, J. J., and Gribik, M., 2,622,120, Battery Terminal Connector

Beese, N. C., 2,622,221, Fluorescent Discharge Lamp

December 23, 1952

Young, J., 2,623,080, Electrode Retainer

Schörg, C. C., 2,623,081, Induction Coil Mounting

Hoke, L., 2,623,082, Dry Cell and Dry Battery Produced Thereof

Gier, J. R. Jr., 2,623,085, Battery Cable Connector

Robinson, P., 2,623,096, Electrical Capacitor

December 30, 1952

Gilbert, L. O., and Buhman, C. C., 2,623,847, Black Chromium Plating

Renzoni, L. S., 2,623,848, Process for Producing Modified Electronickel

Kröger, F. A., 2,623,857, Zinc Sulfide Phosphors Containing Aluminum,

MANUSCRIPTS AND ABSTRACTS FOR FALL MEETING

Manuscripts are now being received for the Fall Meeting of the Society, to be held at the Ocean Terrace Hotel in Wrightsville Beach, N. C., September 13, 14, 15, 16, and 17, 1953. Subjects to be covered at the technical sessions will be Battery, Corrosion, and Electrodeposition.

To be considered for this meeting, triplicate copies of manuscripts or abstracts (not to exceed 75 words in length) must be received at Society headquarters, 235 West 102nd Street, New York 25, N. Y., not later than July 1, 1953.

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2,623,858, Zinc Sulfide Phosphors Containing Aluminum

Kröger, F. A., and Dikhoff, J. A. M., 2,623,859, Zinc Sulfide Phosphors Containing Gallium

Moulton, J. D., 2,623,915, Negative Electrode for Battery Cells

Lyle, A. K., 2,623,969, Electrode for Contact with Molten Glass

Jacquier, M. C. J., 2,624,033, Series Connected Cells with Individual Rectifier Shunts

January 6, 1953

Lund, A. D., 2,624,106, Apparatus for Assembling Storage Battery Elements

Morrison, G. L., 2,624,700, Preparation of Printing Surfaces for Photographing

Austin, R. R., 2,624,701, Electrolytic Titration Cell

De Merre, M., 2,624,702, Separation of Nickel from Cobalt Containing Solutions

Park, R. S., 2,624,763, Electrolytic Fluorine Cell

Moulton, J. D., 2,624,767, Primary Battery

Toulmin, H. A. Jr., 2,624,768, Dextran Battery Separator Plate

Mager, E. L., 2,624,857, Electroluminescent Lamp

Greenlee, W. B., 2,624,858, Gaseous Discharge Lamp

January 13, 1953

Schlain, D., Application 109,054, Electrodeposition of Manganese

Ellis, G. B., Application 121,044, Electrodes of Powdered Metals for Dry Cell

Fastie, W. G., Re. 23,615, Compensated Thermopile

Sadowsky, M., 2,625,493, Method of Manufacturing a Reflective Fluorescent Screen

Mayper, S. A., 2,625,507, Method of Electrodepositing Nickel

Connell, M. W., 2,625,573, Bare Wire Thermocouple Holder

Fuller, L., 2,625,574, Storage Battery Plate Grid

Ellis, G. B., 2,625,575, Dry Battery Cell

January 20, 1953

Brennan, J. B., 2,626,294, Storage Battery Electrode and Method of Making

MacFarland, A. M., 2,626,295, Dry Cell Battery

LITERATURE FROM INDUSTRY

HEATING DEVICES CATALOGUE. A 1953 edition of the catalogue on Calrod electric heaters and heating devices is available. The 60-page, two-color information and buying guide describes the equipments in terms of application, special features, installation, and pricing. General Electric Co. P-122

HARDNESS CONVERSION TABLES FOR STEELS—celluloid card, wallet size—gives approximate relationship between Brinell, DPH (Vickers), Rockwell and Shore Scleroscope hardness values and corresponding tensile strengths of steels. Data from SAE Handbook. International Nickel Co., Inc. P-123

USES OF PERSULFATES. A bulletin, 19 pages, presents a bibliography of the properties and highly diversified uses of persulfates. About 100 references are cited. Buffalo Electro-Chemical Co., Inc. P-124

MER-VAC (RECOVERS MERCURY). Bulletin on specially designed equipment known as the Acme Mer-Vac. Provides a dependable method of recovering mercury globules and mercury-laden dusts, and, at the same time, combats the hazards of mercury vapor poisoning. Acme Protection Equipment Co. P-125

SIMPLE RECORDER CONTROLLER. A 16-page illustrated booklet describes the restyled circular case controller. This instrument has been selected for more than 50,000 installations, to automatically control temperature, pressure, liquid level, humidity or other process variables. The Foxboro Co. P-126

FLUORESCENT LUMINAIRES. A 24-page catalogue of fluorescent commercial and industrial luminaires is available. Detailed descriptions, with photographs and diagrams, discuss each of the luminaires as to applications, models available, features of each, and their dimensions. Style number, description, and prices given. Westinghouse Electric Corp. P-127

INDUSTRIAL X-RAYS. A 44-page illustrated buying guide lists complete and diversified line of accessories and supplies required for industrial x-ray installation. Divided into four basic categories: films and chemicals; radiographic accessories; darkroom accessories; and viewing and filing equipment. Westinghouse Electric Corp. P-128

"CHART OF THE NUCLIDES," 4th ed., shows nearly 1300 different kinds of atoms now known to exist. Full technical data and 8-page descriptive booklet accompany chart. General Electric Co. P-129

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Editorial

The Need to be Different

IN RECENT years some Americans have criticized our native ability to develop new scientific ideas. It is often said here and abroad that Europeans create new scientific ideas and that Americans develop them into commercially useful instruments, machinery, or materials. Some of our large industrial companies support this contention. Industrial leaders are combing European universities, technical institutes, and industries for new ideas and processes. Some Americans are considering the establishment of laboratories in Europe to utilize the creative talent that they find there.

Few will question that our own university research is of a high caliber. However, it can scarcely be denied that it is somewhat channelized into the more glamorous fields of science. Thus, it would appear, for example, that every university must have a cyclotron, a radio-chemical laboratory and a low temperature laboratory. Students graduating from these institutions tend to work in fields in which they were trained. On the other hand few scientists are being trained in such fields as magnetics, inorganic chemistry, and electrochemistry. The latter subjects have been neglected in this country for years although the need for trained people in these fields is great. The industrial leader is forced, therefore, to turn to Europe for ideas and trained personnel in many borderline fields of science.

The author recently returned from a six-month visit to laboratories in nine European countries and has noted certain very interesting aspects of training and environment abroad. This channelizing of scientific activity into certain fields does not occur to the same extent in Europe as in America. The European economy does not permit the continued expansion of scientific activity where large expenditures on capital equipment are involved. Also, the European appears to have a stronger desire to work into borderline scientific fields. This is

(*Continued on next page*)

Editorial (*continued*)

especially true of the Germans. The European also tends to have a more individualistic and much less of a group approach to science.

As a most dramatic example, the French people have the reputation of offering a most fertile soil for all types of ideas. Yet this appears to be not so much due to a rigorous technical training as to a highly individualized approach. At times it appears difficult to find two Frenchmen who will agree on a scientific theory even though they were trained in the same school. The Frenchman prefers his own ideas to his neighbor's and, incidentally, French to foreign ideas.

It is true that this approach has made it difficult for the French to work as a group. Also, many practical problems are never solved except in principle. The French, it is said, tend to assume that one can solve a problem by an idea alone and that once the idea is found the problem disappears. Despite these admitted weaknesses, the desire to think and to think for himself has made the French scientist highly productive of theoretical concepts.

America could use more people with this approach. Conformity should not be our watchword. The desire to be different should be deliberately cultivated in our schools and universities. Only by intelligent individualism can we hope to be successful in producing new creative ideas.

—Earl A. Gulbransen

THE PITTSBURGH INDUSTRIAL AREA

Paul Fugassi[1]

The Pittsburgh Industrial Area is located in the vicinity of the Allegheny, Monongahela, and Ohio rivers and their numerous tributaries. It is localized mainly in Allegheny County, although important sections are to be found in the adjoining counties: Westmoreland, Washington, and Beaver counties to the east, south, and west, respectively.

Allegheny County

Allegheny County has a land area of 725 square miles and a water area of 33 square miles. This is about 1.5 per cent of the area of the state of Pennsylvania. In this region are located 4 cities, 78 boroughs, and 48 townships. As of January 1, 1952, the assessed value of real estate in the county as used for taxation purposes was $2,262,187,620. This figure is about 20 per cent of the total assessed value of real estate for the entire state of Pennsylvania. The assessed valuation of personal property for the inhabitants of Allegheny County was $617,683,050. This assessment is made on all interest or dividend paying investments except bank accounts, obligations of corporations chartered in Pennsylvania, obligations of those out-of-state corporations which pay a franchise tax, and tax-exempt securities. The Allegheny County personal property assessment is about 22 per cent of the personal property assessment for the entire state. In 1950 the population of Allegheny County was 1,515,237 or about 14 per cent of the population of Pennsylvania. In population Allegheny County is eighth in the United States and ranks second in Pennsylvania. Its population is greater than the population of seventeen states. In the county there is one automobile for each four persons and one telephone for each three persons. According to the latest available figures (1948), Allegheny County produced products valued at $3,162,100,000 and had 247,749 persons employed, earning an aggregate salary of $800,750,900.

Although Allegheny County is highly industrialized, it is estimated that about 92,000 acres in the county are capable of being farmed and actually 79,500 acres are under cultivation, representing about 17 per cent of land area of the county. Of the remaining land, a considerable portion is represented by steep hillsides, ravines, etc., so that actually the industrialized area is concentrated and is located near or at the river system.

The river system comprises three major streams: the Allegheny, Monongahela, and Ohio rivers. The Allegheny River enters the county from the northeast and joins the Monongahela River, which enters the county from the southeast, to form the Ohio River at the Point in Pittsburgh. The Ohio River leaves the county in a northwest direction, connects with the Beaver River in Beaver County, and then turns southwest to eventually join the Mississippi River at Cairo, Illinois. The rivers are of reasonable size and fairly wide. At Pittsburgh, the Allegheny and Monongahela are 800 feet wide on the average, and the Ohio is about 1100 feet wide.

Many streams and creeks flow into the three major rivers through valleys, ravines, and gullies. The terrain is quite hilly. Valleys in most cases are narrow and deep; depths of 100 feet are not uncommon. Such terrain poses many difficulties for construction and it is inevitable that utilization of land of this type necessitates the construction of many bridges. The Allegheny County Department of Works has a Division of Bridge Maintenance which takes care of 264 major and minor bridges over rivers and named streams and some 346 minor structures. The city of Pittsburgh maintains some 150 bridges. Some bridges are under supervision of the state and others are privately owned by railroads, railways, etc. Altogether there are about 800 bridges in Allegheny County.

Pittsburgh

Pittsburgh is located at the junction of the Monongahela, Allegheny, and Ohio rivers and is the largest city in Allegheny County. It covers an area of 47 square miles and has a population of 676,806. Its assessed valuation of real estate is $1,043,592,185 and the personal property assessment of its inhabitants is $464,728,920. These figures correspond to 50 per cent of the real estate valuation and 75 per cent of the personal property assessment of Allegheny County.

Although the Ohio Valley was explored by the French explorer, Robert de La Salle, in 1679, the first structure, Fort Prince George, was started at the Point by the English in 1754, captured by the French before its completion in the same year, and renamed Fort Duquesne. After several unsuccessful attempts, the French were driven out in 1758 and the fortifications were reconstructed and named Fort Pitt. It served as an important frontier outpost and guard against the Indian raids until the Indians were defeated in 1763 at Bushy Run. As the Indians left Western Pennsylvania and the frontier moved westward, Fort Pitt lost its importance and was abandoned after the Indians were completely defeated at Fallen Timbers (Ohio) in 1794.

The initial importance of Pittsburgh was that it served as the gateway to the vast interior waterways of the United States. As the frontier moved westward, opportunities arose for river trade with the settlements along the Ohio River. Because it was difficult and expensive to transport eastern goods over the mountains, manufacturing started in Pittsburgh. Iron ore was discovered on the western slope of the Allegheny Mountains in 1780. Coal had been found previously. The first blast furnace to be erected in the city of Pittsburgh was built in 1792 but was in operation for only two years. Smelting operations for a number of years were conducted near the ore supplies. The first successful furnace

[1] Carnegie Institute of Technology, Pittsburgh, Pennsylvania.

Courtesy, Pittsburgh Chamber of Commerce

This view of "The Point," Pittsburgh, shows the site for the new Point Park, in the foreground, the first three buildings of Gateway Center, and the "Golden Triangle."

in the city of Pittsburgh was constructed in 1859 and was operated until 1927. By 1865 Pittsburgh had 46 iron factories, 7 steel manufactories, and 31 rolling mills, and had been recognized as an iron and steel center.

Natural Resources

The continued growth of the Pittsburgh Area is undoubtedly due to the abundant mineral and fuel resources present in the district.

Coal was discovered very early in Pittsburgh. A visitor to Fort Pitt in 1760 described a coal mine located opposite to the Fort on the south bank of the Monongahela River. The famous Pittsburgh Bed starts at Pittsburgh and extends south into West Virginia. The eastern limit is in Westmoreland County and the western limit in the State of Ohio. The Pittsburgh Bed averages 7 feet in thickness and the bed is sufficiently close to the surface so that drift mines can be used or, in some cases, strip mines. Another important bed near Freeport called the Thick Freeport Bed has an area of 115 square miles and has been mined for many years. Other beds are also known, but because of their depth have not been developed. After nearly 200 years of mining, the district still has adequate coal resources.

Petroleum and natural gas resources were first developed in 1858. The Pittsburgh Area is in the center of the Appalachian Field. This field starts in New York State and extends southwest through Pennsylvania and Ohio into West Virginia and Kentucky. Both gas and oil pools are found in this field. In some respects the city of Pittsburgh stands on the dividing line between oil and gas wells. Wells to the north and west of Pittsburgh give oil with little gas. Wells to the south and east of Pittsburgh give mainly gas with a little oil. Natural gas was first used in the steel industry in 1874. Although the gas fields in the Pittsburgh area are still producing, local consumption exceeds the local production, and it is necessary to import natural gas from the southwest. Local petroleum production is also exceeded by the local demand and importation of petroleum and petroleum products is necessary.

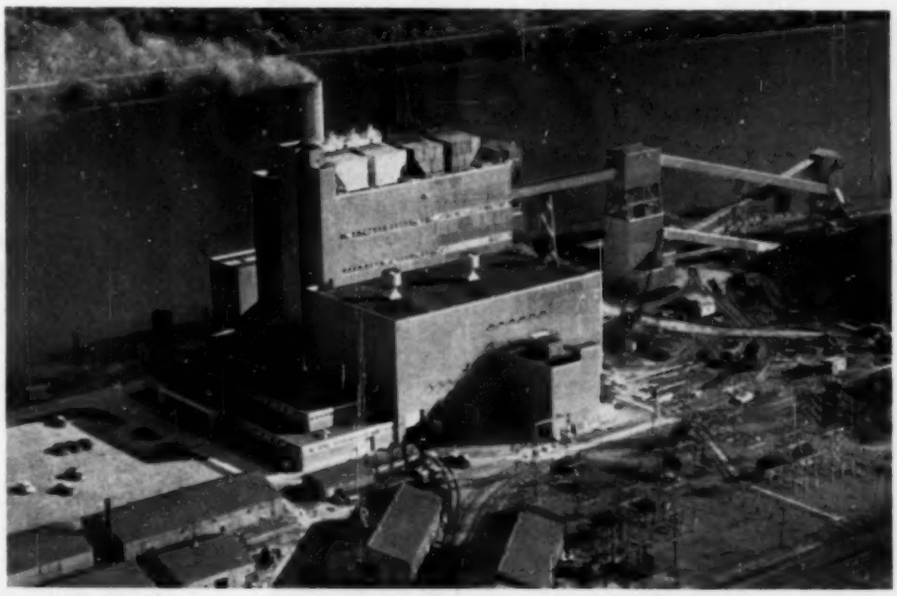
Limestone and sandstone deposits are found in the Area. A practically inexhaustible source of sand and gravel is furnished by the river system. Millions of tons of sand and gravel are dredged from the rivers each year. Adequate supplies of clay are available for refractories.

Transportation

The Pittsburgh district is served by 22 railroads. Six of these are trunk lines and the other 16 are industrial and terminal-switching railroads. The principal lines are: Baltimore and Ohio; Bessemer and Lake Erie; Buffalo, Rochester, and Pittsburgh; Pennsylvania; Pittsburgh and Lake Erie (New York Central); and Pittsburgh and West Virginia.

Heavy tonnages are shipped by the river system. The Ohio River is navigable over its entire length. The Allegheny and Monongahela Rivers are navigable to a considerable distance upstream from the city of Pittsburgh. In 1951, 44,000,000 tons of freight travelled on the Allegheny, Monongahela, and Ohio rivers. Of this tonnage 70 per cent was coal, 13 per cent was sand and gravel, 8 per cent petroleum products, 5 per cent iron and steel, and the remaining 4 per cent coke and miscellaneous materials. Shipment of steel products by river was started in 1921. The northernmost city to which such shipments have been made is Minneapolis, and the southernmost city is, of course, New Orleans. River traffic on

the Monongahela in 1951 was about 32,000,000 tons, maintaining its reputation as "the busiest little river in the world." The same year river traffic on the Allegheny was 4,250,000 tons. River transportation has been of importance since the earliest days. Regular shipping of coal by river boat started in 1817. Because of the river system, shipbuilding has been an important industry. In the early eighteen hundreds, sailing vessels were constructed at Pittsburgh and cleared from the Port of Pittsburgh for Europe. This procedure could be followed only once as the vessel could not ascend the Mississippi and Ohio river systems and had of necessity to clear from other ports for future trips. The construction of ocean vessels was not resumed until the second World War when many landing craft were constructed here. The shipbuilding industry normally is concerned with river tugboats and barges. In 1952, 173 vessels were launched Of this number 116 were coal barges carrying 1,000 to 2,500 tons. At times a serious transportation problem is solved by use of the river system. The coils for the cyclotron at the Carnegie Institute of Technology were constructed at the Brooklyn Navy Yard and because of their bulk and weight could be transported neither by rail nor by truck. They were sent via the Atlantic Ocean and the Gulf of Mexico to New Orleans and transhipped there to a river boat which brought them up the Mississippi, Ohio, and Allegheny rivers to a point a few miles away from their final destination.



The new Elrama Power Plant of the Duquesne Light Company, supplier of electric power in Allegheny and Beaver counties. The exterior and interior surfaces of the building are aluminum sheet.

Courtesy, Duquesne Light Company

Electric Power

In Allegheny and Beaver counties, power is supplied by the Duquesne Light Company. The counties to the north, east, and south of Allegheny County are supplied by the West Penn Power Company. The Duquesne Light Company system is quite limited in area. Its 66,000-volt transmission ring has a circumference of only 81 miles. It has, however, a large power capacity which is at present about 1,000,000 kw. The Duquesne Light Company is in the seventh year of a nine-year expansion program, scheduled for completion in 1955 at which time its capacity will be 1,225,000 kw. All of its power is obtained from steam, using coal as the fuel. The Duquesne system is tied in with the Pennsylvania Power Company system in the north, the Ohio Power Company system in the west, and the West Penn Power system on the east. About 120,000 kw can be obtained from these other systems. Many companies in the Pittsburgh Area generate all or part of their power requirements. Some of these private power installations are tied in with the Duquesne system and can, in emergencies, furnish power to the network. The United States Steel Company plants could furnish about 60,000 kw and the gigantic butadiene-styrene plant of the Koppers Company at Kobuta can furnish about 25,000 kw. Altogether about 100,000 kw of additional power are available from such sources. Of the power sold by Duquesne Light Company, 66 per cent is for industrial use, 14 per cent for miscellaneous commercial use, and 20 per cent for residential use.

The West Penn Power Company is part of a system which supplies power in Maryland, West Virginia, and Pennsylvania. It serves an area of about 24,000 square miles and has transmission rings over 1000 miles in length. Its closest power station to the Pittsburgh district is at Springdale on the Allegheny River, 17 miles from the city of Pittsburgh. The major portion of its power is steam-generated but it does have several hydroelectric stations. The Springdale Station has a capacity of 315,000 kw and is being expanded to an ultimate capacity of 450,000 kw.

Distribution of Industries

In 1948, according to the Pennsylvania Industrial Survey, Allegheny County produced goods valued at $3,162,100,000 Of these goods, 90 per cent fell in the following five categories metals and metal products, 68 per cent; food and kindred products, 12 per cent; chemical and allied products, 5 per cent; paper and printing, 3 per cent; mine and quarry products, 2 per cent. These figures illustrate the importance of iron production for Allegheny County as it is the only metal produced in quantity. When it is considered that the chemical industry is closely connected with the steel industry in this district because of by-product coke ovens, and the mining industry also is closely connected with coke and power production, the importance of steel production to industrial activity in Allegheny County is obvious.

Another way of determining the distribution of industrial activity is to examine the distribution of employees by industries. In November 1952, the percentage distribution of employees by industry in the Pittsburgh Area, which comprises Allegheny, Beaver, Washington, and Westmoreland counties, was as shown in Table I (see next page). Inspec-

TABLE I. *Distribution of employees by industry in Pittsburgh Area*

Industry	% of Total employed
Primary metal	44.4
Electrical machinery	9.9
Fabricated metal	9.5
Machinery (other than electrical)	7.2
Glass, clay, stone	6.7
Food	6.1
Petroleum and coal products	3.1
Transportation equipment	2.1
Printing and publishing	2.1
Chemicals	2.0
Instruments	1.9
Textiles and apparels	0.9
Lumber and furniture	0.8
Paper and paper products	0.8
Other	2.5
	100.0

tion of the figures shows again the importance of iron and steel production in the Pittsburgh Area.

Iron and Steel Production

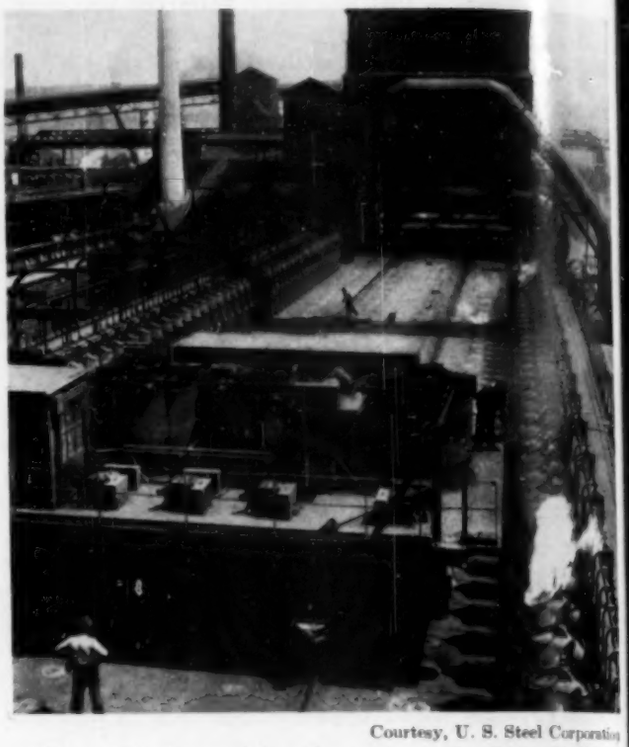
In the Pittsburgh Area there are 48 blast furnaces of which 45 were reported in operation in November 1952. These furnaces have a yearly capacity of over 14,000,000 tons, most of which is pig iron with a relatively small production of ferroalloys. The number of by-product coke ovens is about 2600. These are of the Koppers or Koppers-Becker type. Over 1500 of these ovens are located at the Clairton plant of the United States Steel Company, making it the largest coking plant in the world. The annual production of by-product coke is about 12.6 million tons. During the last war appreciable quantities of coke were made in the old type beehive ovens. Coke is still being produced in this way.

There are in the Pittsburgh Area 176 open-hearth installations, 6 Bessemers, and 24 electric furnace and crucible steel installations. The yearly capacity of the electric furnace-crucible steel furnaces is about the same as that of the Bessemer converters; each is about 0.6 million tons a year. The open-hearth capacity is near 14 million tons per year.

The area has adequate rolling-mill and fabrication facilities so that the steel and iron produced in the district is shipped in all possible forms: structural beams, plates, rod, sheet, wire, pipe, etc. Steel clad with metals such as copper, silver, etc., is also produced, together with galvanized and tin products.

Chemical By-Products

When coal is heated in a by-product oven, one ton of coal gives about 1,500 pounds of coke, 1000 cubic feet of coal gas, and around 10 gallons of coal tar. Coal gas contains principally hydrogen and methane, but many other compounds are present such as benzene, toluene, naphthalene ammonia, hydrogen sulfide, hydrogen cyanide, and cyanogen. After poisonous components have been removed, the gas is an excellent fuel. Ammonia is removed as ammonium sulfate. Hydrocarbons of low volatility can be removed by scrubbing the gas with oil. Coal tar is a very complex mixture from which over 150 compounds have been isolated to date. The components of coal tar fall into three categories: (*a*) neutral compounds such as hydrocarbons; (*b*) tar acids such as phenol and cresols; and (*c*) tar bases such as pyridine. Tar



Courtesy, U. S. Steel Corporation

View of the by-product coke ovens at the Clairton Plant, United States Steel Corporation, the largest coking plant in the world.

acids are soluble in dilute aqueous solutions of sodium hydroxide and the tar bases are soluble in dilute aqueous solutions of sulfuric acid. Extraction methods and distillations serve to separate the various components. From coal tar can be separated benzene, toluene, naphthalene, phenanthrene of the neutral compounds, phenols, cresols, and xylenols of the acid compounds, and pyridine of the basic compounds. The large production of coke in the Pittsburgh Area results in a large supply of chemical compounds which have direct uses or can serve as the basis of the production of other products such as styrene, phthalic anhydride, etc.

Each pound of pig iron produced in a blast furnace is accompanied by the production of about 0.5 pound of slag. Disposal of slag is not an insignificant item in the cost of pig iron. The principal use for slag is the manufacture of cement. Two plants in the area prepare cement from slag, but the amount of slag produced far exceeds the amount used in cement manufacture. Slag, in granulated form, prepared by quenching molten slag in water, or in lump form, is used for fills, as a gravel substitute, or as a soil conditioner for lightening heavy soils. Such uses consume only small amounts of the yearly production and the excess is stored in large dumps covering many acres. In the war years slag dumps were "mined" to recover scrap iron.

Electrochemical Industries

The largest application of electrochemistry in the Pittsburgh Area is to found in the production of tin-plated steel. To a lesser extent electrothermics is represented in the production of electric furnace steel and in the production of zinc.

No electrolytic reduction processes are in operation in this area. Although the Aluminum Company of America has several large plants at New Kensington, these units are mainly fabricating plants. A number of electrochemical treatments are used there to provide decorative and protective finishes to a variety of aluminum products. Alumilite coatings

formed b electrolytic oxidation of the aluminum surface in a sulfuric id electrolyte are applied to Kensington Ware, aircraft parts, and other articles. Oxide coatings formed in a chromic acid electrolyte are also applied to some tanks and aircraft parts. Two electrochemical processes are used to make highly reflecting aluminum sheets employed as specular reflectors for lighting applications. These involve electrolytic brightening of the surface in a fluoboric acid electrolyte to obtain high reflectivity and subsequent application of a clear transparent alumilite coating to protect these surfaces.

Tin Plating

In a recent summary of electrolytic tin plating, D. A. McArthur[2] listed the electrolytic tinning lines in existence or under construction in June 1952. The total number of lines in the world was 41 with an annual production of 4,755,000 tons of 0.5-lb plate. Tin plate rated as 0.5-lb plate contains 0.5 lb of tin coated on both sides of 217.78 square feet of steel (one base box). Of the world total, 33 lines are located in the United States with a production of 3,845,000 tons per year of 0.5 lb plate. In the Pittsburgh Area 6 lines are in operation; 3 at the Aliquippa plant of Jones and Laughlin Steel Corporation, and 3 at the Irvin plant of the United States Steel Corporation. The annual production of these six lines is about 1,000,000 tons of 0.5-lb plate.

Electrolytic tin plating became a necessity with the outbreak of war in the Far East because of the limited supply of tin available to the United States. Before this time the production of electrolytic tin plate was very small and most tin plate was prepared by hot dipping. The standard coating for hot-dipped tin plate was 1.50 lb of tin per base box. To conserve tin supplies it was necessary to reduce the thickness of the tin coating. It was discovered that the thinnest practical coat obtainable by the hot-dip process was 1.25 lb of tin per base box. Electrolytic lines could be operated to produce coatings between 0.25 lb to 1.00 lb of tin per base box. Tin plate was standardized at 0.5 lb per base box which was equivalent to saving one pound of tin for each base box of plate produced. The 0.5 lb per base box plate is only 0.00003 inches thick and in many cases must be covered with a suitable lacquer to have the desired corrosion resistance.

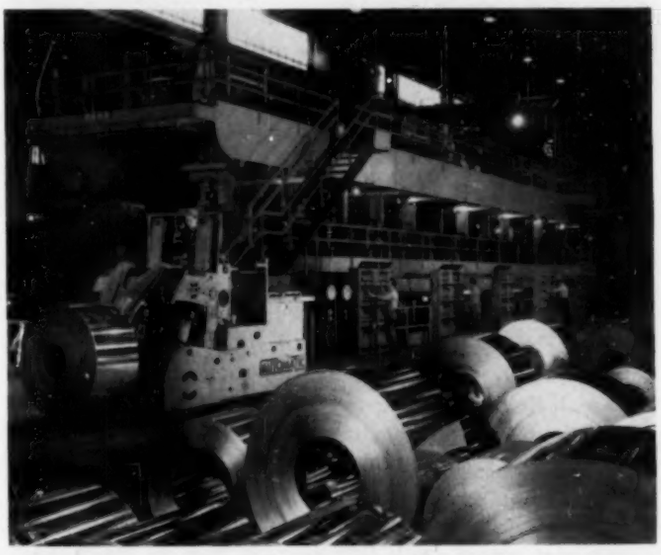
Practical tin plating installations use either alkaline plating baths (Crown) or acid plating baths (Ferrostan or Weirton). In the Crown and Ferrostan lines, the continuous sheet, in being plated, moves vertically up and down through the plating bath while in the Weirton line the continuous sheet runs horizontally through the plating bath. Theoretically, the acid baths are more efficient and permit higher current densities to be used. On the other hand, alkaline plating baths involve fewer corrosion problems and require less cleaning of the sheet steel before plating. According to McArthur's table more acid lines have been installed in recent years than alkaline lines. The present ratio of acid to alkaline lines in the United States is 20 to 13. All foreign installations are of the acid type. All three types of lines are in operation in the Pittsburgh Area.

Excluding the mechanical operations at the beginning and end of a tin plate line, all lines consist of three sections: (*a*) a pickling section where the surface of the sheet is cleaned; (*b*) a plating section; and (*c*) a melting section to fuse the electrodeposited tin plate.

In alkaline lines the cleaning operation consists of an acid pickling in 10 to 15 per cent sulfuric acid at 150° to 160°F. No alkali cleaning is necessary because of the alkalinity of the plating solution. In acid lines the sheet is first cleaned in an alkaline bath and electrolytic action is employed using current densities of 50 to 400 amperes per square foot. After alkali cleaning, the sheet in acid lines is acid pickled in sulfuric acid. In the acid pickle either a 20 to 25 per cent sulfuric acid at 200° to 220°F is used or, if supplementary electrolytic cleaning is employed, more dilute acid can be used and also lower temperatures. Electrolytic cleaning reduces the necessary immersion time by one-half or more.

In the plating section of an electrolytic tin line, a number of precautions must be taken in order to produce satisfactory tin plate economically. The linear speed of the continuous strip must be closely controlled in order to obtain a plate of uniform thickness. The motors moving the strip are of the d-c constant speed type. The linear speeds used depend on the mechanical arrangements utilized at the exit side of the line. If the line is equipped with shear and stacking units, the linear speed cannot exceed 900 feet per minute or about 10 miles per hour. If the continuous plated strip is recoiled, higher linear speeds are possible. In fact, linear speeds up to 2,500 feet per minute or about 28 miles per hour have been used.

In all types of line the electrical current is led into the continuous strip by means of conductor rolls. In acid lines the conductor rolls are copper; steel is used in alkaline lines. In acid lines the electrolyte is circulated, while in alkaline lines the electrolyte is not circulated. Smaller current densities must be used on the tin electrodes in the alkaline type lines, and the tin electrodes are larger than those in acid type lines. All tin-plating lines require large amounts of low voltage direct current for the plating, electrolytic cleaning, and electrolytic pickling. Early installations had a capacity of 45,000 to 60,000 amperes at 6 to 12 volts. Later installations have current capacities up to 180,000 amperes with voltages between 15 and 18 volts. In practically all installations the necessary d-c voltage is obtained from motor-generator sets. Rectifiers have not found any considerable use. All plating sections are furnished with current regulators to handle variations in the linear speed of the strip. Such regulators must function over wide ranges of linear speed as the line



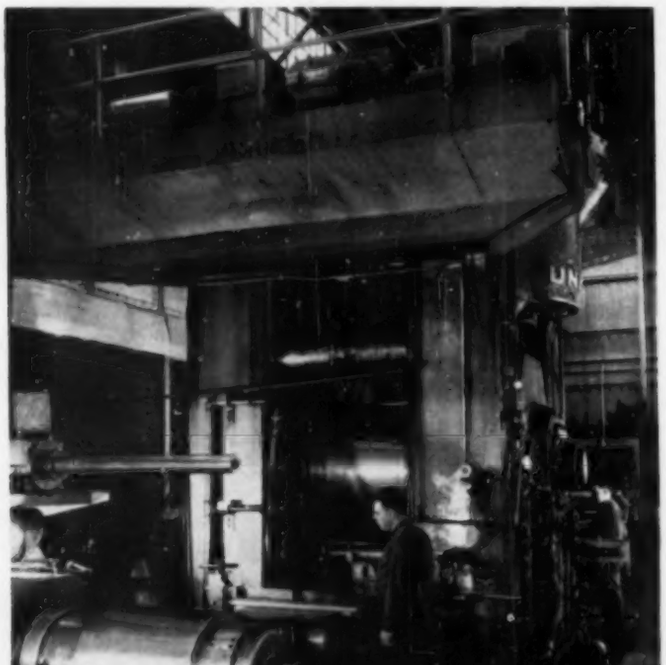
Courtesy, Jones & Laughlin Steel Corporation

Shown here is one of the new electrolytic tin plate lines, horizontal type, in operation at the Aliquippa Plant of Jones and Laughlin Steel Corporation.

[2] D. A. McArthur, "Electrolytic Tin Plate," Wean Engineering Company, Inc., Warren, Ohio.

at times must be slowed down for welding or other mechanical operations.

A satisfactory tin plate is produced only if the tin coating is fused, and every tin-plating line has a melting section where this is done. Fusion of the tin coating improves adherence of the tin to the steel and also reduces the porosity of the tin coating. Three types of heating have been employed; inductive, radiant, and conductive. In inductive heating the continuous strip passes through a series of coils energized from vacuum tube oscillators operating at a frequency of 175 kilocycles. The energy output of such oscillators in some installations has been as high as 1800 kw. This capacity far exceeds that used even in the largest radio station. Inductive heating is expensive but can handle sheet operating at any practical linear speed. It is also possible to regulate the output very closely by relatively simple electronic methods



Courtesy, Allegheny-Ludlum Steel Corporation

Facilities for rolling titanium strip are shown at the West Leechburg Plant of Allegheny-Ludlum Steel Corporation.

using a photoelectric tube scanner to maintain a fixed position for the flow line of the molten tin. In radiant heating the continuous strip is passed through electric or gas-heated furnaces. Radiant heating produces a satisfactory product but cannot be controlled with the same flexibility as electrical heating. For this reason radiant heating has been used in only a few tin-plating lines. In conductive heating a low-voltage, high-amperage current is passed directly through the steel strip. Conductive heating from the standpoint of flexibility and cost is comparable to inductive heating.

After melting of the tin coating, the strip is subjected to rinsing and chemical treatments which clean the surface. Electrolytic action, with the sheet in turn as anode and cathode, sometimes supplements chemical treatments.

In looking at the production of tin plate in the United States over the ten-year period, 1941–1951, it is interesting to note that the production of hot-dip tin plate was about 3.2 million tons in 1941 and had dropped to about 1.6 million tons in 1943. The production of hot-dip plate has remained at about that figure for nine years. In 1941 the production of electrolytic tin plate was practically nothing and reached about 0.8 million tons in 1945. Since 1945 continuous expansion of electrolytic tin plate production has taken place and in 1951 the production was about 2.9 million tons. It has been stated that 80 or 90 per cent of the total tin plate production will be electrolytic tin plate but other predictions are that all tin plate will be produced electrolytically. It should be noted that electrolytic tin plate having 1.0 lb of tin per base box has been successfully produced and that this material is competitive with hot-dip tin plate of 1.25 lb of tin per base box. The recent suggestions for "differential tin plate" are of interest. In this type of plate one side of the sheet has a heavier tin coating than the other side. For food packs the heavier coating is used for the inside of the can and the lighter coating is the outside. "Differential tin plate" is in production and is available in practically all possible combinations. A differential tin plate designated as 1.00/0.25 has a coating of 1.00 lb of tin per base box on one side and 0.25 lb of tin per base box on the other side. "Differential tin plate" cannot be prepared by the hot-dip process.

Future Developments

As a fuel center, the utilization of coal for the production of gaseous and liquid fuels and as a starting material for the production of chemicals is an item of interest to industry in the Pittsburgh district. The Bruceton (Pa.) Station of the United States Bureau of Mines has been doing extensive research work on the production of liquid fuels from coal. Other research units are interested in other phases of coal utilization. Considerable advance has been made in lowering of coal mining costs by mechanization. As with other producers of steel and iron, the companies in the Pittsburgh Area are prospecting for new sources of iron ore and for economical methods of utilizing the lower grade iron ores available on the Mesabi Range and also iron ore deposits not worked extensively since the discovery of the Mesabi Range. The metallurgy of titanium is under development in the district. In the near future tin will not be available and work is progressing on the development of protective coatings, which will give, with use of suitable lacquers, a satisfactory and economical substitute for tin plate.

Because of its river system, the Pittsburgh Area has adequate water resources. However, with such a system stream pollution becomes a very important problem. Strip mining and other coal mining operations contribute large amounts of sulfuric acid to the water system. The sulfuric acid arises from oxidation of sulfur containing residues left after removal of the coal. Both water and air are essential for the reaction. Proper arrangement of drainage facilities, sealing of worked-out coal mines, and other arrangements have been used to reduce sulfuric acid pollution. Waste-disposal receives serious attention, but considerable research work still needs to be done. A rigid smoke control law has reduced the smoke and fog to a considerable degree.

In recent years, several large users of steel products have erected fabricating plants in the Pittsburgh Area and it is to be expected that some additional diversification of industrial activity will result. With the active interest now displayed and the expenditures being made on research, it can be anticipated that the Pittsburgh Area will continue its growth for many years.

Feature Section

Electrolytic Grinding or Machining of Metals[1]

O. W. Storey[2]

Electrochemistry apparently is destined to aid a metal-working industry threatened by the shortage of the diamond bort so essential in the past for the grinding and shaping of hard metals and other materials, such as the sintered carbides. Controlled anodic dissolution of these hard materials, developed as an electrolytic grinding process, has now reached the stage where it seems likely to displace diamond grinding at least sufficiently to end the critical diamond bort situation. Although two other electrochemical hard-metal-working processes (electroarcing and electrosparking) also are promising, the Minerals and Metals Advisory Board of the National Research Council, in its evaluation of the several processes,[3] held that the electrolytic grinding method was particularly promising for flat offhand grinding as applied to sharpening of single-point tools and particularly to the finishing of the sintered carbides. These grinding operations are the largest consumers of diamond bort. The report further stated that the process also seems well suited to the sharpening of milling cutters and broaches, the grinding of projectile cores, and the machining and grinding of compressor disks. It also has been used successfully in the sharpening of twist drills.

The intentional electrolytic removal of metals has been practiced for many years as in electropickling and in electropolishing. However, the controlled electrolytic removal of metal as in the shaping of metals has not been practiced commercially. The possibilities of the anodic process were demonstrated dramatically by the late Dr. C. F. Burgess at the 1941 Chicago meeting of the Society in his "Electrolick Work-Shop." In the Electrolick pamphlet that was distributed he called attention to the striking differences between the mechanical and electrolytic methods for displacing metal, the first being a method of "brute force and violence" and the second being a "cool, steady, nondeforming magic of electrolytic-anodic removal of metal." However, except for a few isolated applications, and despite its intriguing appeal, Dr. Burgess' hobby failed to develop commercially during the following decade. Although the hardest metals and the sintered carbides can be dissolved readily by anodic action at low potentials, it was found difficult both to control the action so that only unwanted metal was removed and to remove the metals at rates comparable to those obtained by mechanical methods. These two hurdles now seem to have been overcome in the grinding field.

Super-Cut, Inc., of Chicago, manufacturer of diamond grinding wheels and tools exclusively, is sponsoring the development of the electrolytic grinding method devised by George Keeleric. His method utilizes a fast-moving cathode having spaced-apart insulating particles imbedded in its surface and protruding evenly above it for spacing the cathode from the work. The method and equipment are being tested by a number of users of large quantities of sintered carbides and hard-metal tools, including Buick, Frigidaire, Ford, Excello, Chrysler, and Kenna-Metal. The development is of particular interest to electrochemists because there were utilized in the solution of the problem several phases of electrochemistry. As practiced at present, the success of the Super-Cut process is due to: (*a*) the utilization, without appreciable arcing, of high electrode current densities up to 1500 amp in.^{2} with closely spaced electrodes 0.007 in. (0.0178 cm) apart; (*b*) effective removal of insulating insoluble residues from the anode surface; (*c*) accurate spacing means between anode and cathode; and (*d*) automatic control of the voltage so that the operation is conducted at the highest possible current density at all times, that is, without causing arcs or "hot" sparking to occur.

In the process as developed, the diamond grinding wheel remains as the most important element, but its function differs essentially from the ordinary diamond grinding in that the diamonds no longer operate on the metal or other hard stock. Instead, they function primarily as insulating spacers between the stock anode and the revolving nickel cathode surface in which they are anchored, and, secondarily, as a mild abrasive to keep the surface of the anode free of films of insulating insolubles. These films, which are relatively soft, consist primarily of oxides which are formed when the carbides are anodically dissolved. The diamonds are more economical to use than aluminum oxide or silicon carbide because the latter do not stand up sufficiently long. The diamonds, therefore, are still used, but their life has been extended greatly. In one reported test in which chipbreakers were ground, the diamond wheel cost was decreased from $107.87 per cubic inch of carbide removed for conventional grinding to 68 cents for electrolytic grinding. To the 68 cents must be added 8 cents for the power required to dissolve the carbide anodically. These costs are subject to further checking but nevertheless are indicative of the conservation of diamond bort that may be effected.

The structure of the ordinary diamond grinding wheel has been modified to obtain maximum electrolytic grinding efficiency. A single layer of diamonds is used to surface the electroformed nickel cathode facing of the wheel. These diamonds are of coarser mesh than previously used for this work and the particle concentration has been increased considerably. This increased concentration helps to prevent intermittent contact between the work piece and the cathode. This would cause arcing and sparking with consequent impairment of the finish of the work and possibly erosion of both the work piece and the wheel electrode, which, in form or contour grinding, is very detrimental to the accuracy of machining. The particles must be spaced sufficiently apart to allow flow of electrolyte between the work piece and wheel.

With close spacing of the electrodes (0.007 in. or 0.0178 cm) rapid replenishment of the electrolyte is essential if the high current densities needed for rapid stock dissolution are em-

[1] It is believed that this description of one sort of Applied Electrochemistry will be of considerable general interest to our readers. (*Ed.*)

[2] Chicago Regional Editor, JOURNAL of The Electrochemical Society.

[3] *J. Metals*, **4**, 378 (1952).

ployed. This rapid replenishment is accomplished by supplying a stream of electrolyte continuously to the rapidly rotating diamond-faced cathode wheel, its surface speed being comparable to that employed in ordinary grinding, 5000 to 6000 surface-feet per minute. It therefore has been possible to use the ordinary tool-grinding machine for electrolytic grinding after insulating the tool spindle from the rest of the machine and conveying the current to it by suitable means. It is estimated that standard grinding machines can be converted locally at a cost not exceeding $500.00 per machine.

The electrolyte used is a conductive salt solution, the salt depending upon the composition of the work piece. The highly conductive sodium salts have been mainly used. The electrolyte should not corrode the machine parts and carbide tool shanks. This requirement eliminates the highly effective chloride salts and particularly sodium chloride. Furthermore, the electrolyte should be nontoxic because of the mist which is formed by the rapidly revolving wheel. Salts of certain organic acids are now giving satisfactory results, but this is a field for continued research. Sodium silicate solution may be used as electrolyte to help decrease edge erosion as it forms a protective coating on adjacent surfaces. However, it decreases the rate of cutting. Because the electrolyte apparently can be used indefinitely, its cost per unit of metal removed is very small.

The diamond particles are anchored in the electroformed nickel cathode perimeter of the wheel during the plating operations. In the fabrication of the wheel the first step is to mount the single layer of diamonds in a very thin adhesive film on a steel ring. A thin layer of copper is plated onto this surface, followed by the nickel. The copper is plated to a thickness equal to the depth that the diamonds are to be exposed at the wheel surface. The nickel is plated to the desired thickness of about 1/8 in. (0.32 cm), completely enveloping the parts of the diamonds exposed above the copper. This composite structure is now mounted on the base wheel after which the steel ring is removed. The exposed copper deposit is dissolved anodically in a cyanide bath, thereby uncovering the tops of the diamonds which are firmly held in the underlying nickel matrix. The wheel must run absolutely true and new procedures are used to obtain this result handily.

The electroformed nickel or nickel-cobalt alloy must be a low-stress deposit. A dense, tough, hard deposit is necessary to hold the diamonds securely. It also must be a good conductor of electricity and be highly abrasive resistant. Such nickel has been found superior to the standard metal bonds and standard types of impregnation used in standard diamond wheels.

The automatic control of voltage to maintain the maximum current density without causing arcing between the nickel cathode wheel and the work piece has been effected through a rectifier of special design. Its output voltage, usually about 25 volts, is automatically controlled to give maximum voltage and thereby maximum currents at all times for any particular work operation. If too high d-c voltage is delivered to a grinder for a given spacing, sparking and arcing occur. These must be avoided. To accomplish this close control an electronic unit built into the rectifier lowers the voltage as soon as excessive or "hot" sparking occurs. The principle involved is based upon the fact that arcs and sparks produce a superimposed a-c current on top of the d-c current. This a-c current is picked up by the control unit, amplified, and rectified, and the resulting current is then used to reduce the input power to the rectifier by reducing the saturation of reactors in series with the input power line. This action takes place practically instan neously. The control unit may be adjusted to: elimi nate sparking; allow a certain amount; entirely cut off the d-c v age; or lower it to any desired level. For most pur poses adjusted to allow a certain amount of cold sparking and to duce the voltage only to such an extent that arcs cannot maintained. The rectifier eliminates the human element in adjustment of the voltage and also allows the operator to erate at the highest possible current density under any con tion. It would be difficult or impossible to do this while m ually operating the grinder without the automatic cont Consequently no additional training of personnel is requir The operator maintains only sufficient pressure on the wh to scuff off the oxides formed in the work.

In electrolytic grinding the metal is removed at the ano substantially in accordance with Faraday's law. Using described method and equipment it is possible to operate such current densities that the rate of metal removal is least no slower than in normal diamond grinding. At one sh electrolytic grinding is doubling the rate of metal removal one specific job.

Experience to date shows that no stresses or strains are up by electrolytic grinding in the worked piece. Because of extremely cool grinding, no hidden cracks have been fou such as are often caused by heat generated if normal grind is done incorrectly.

Electrolytic grinding produces a matte surface in contrast the parallel scratches and grooves produced by nor diamond grinding. On the other hand, the matte surf finish consists of minute and slightly oval-shaped moun Finishes can be obtained as fine as 4 micro inches provid the diamond wheel is right and is running true.

Electrolytic grinding produces a slightly rounded edge the part of a tool that is being ground, that is, the very t edge where the electrolyte first hits the tool. The amount rounding varies with the type of carbide. Where a slight rounded or chamfered edge is preferred this may not objectionable.

At present the data indicate that tools shaped by electr lytic grinding have no shorter life than diamond-ground too

Experience has been too limited to provide reliable data and to determine the sphere of usefulness of electrol grinding. However, experience to date indicates that elect lytic grinding probably will effect economies in the grinding sintered carbides and that the diamond bort shortage may relieved by a process that will not add to production co Super-Cut, however, warned early in October 1952, t "until sufficient reports have been received relative to merit of electrolytic grinding from all sources so exp menting, conclusions should be questioned."

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Current Affairs

News Notes in the Electrochemical Field

Gordon Research Conferences, June 16-Sept. 4

The Gordon Research Conferences, sponsored by the American Association for the Advancement of Science, for 1953, will be held from June 16 to September 4 at New Hampton School, New Hampton, New Hampshire. The facilities of the school have been made available for the Conferences.

The Gordon Research Conferences were established to stimulate research in universities, research foundations, and industrial laboratories. This purpose is achieved by an informal type of meeting consisting of the scheduled lectures and free discussion groups. Sufficient time is available to stimulate informal discussions among the members of a Conference. Meetings are held in the morning and in the evening, Monday through Friday, with the exception of Friday evening. Afternoons are available for recreation, reading, resting, or participation in discussion groups as the individual desires.

The object of the program is not to review the known fields of chemistry, but primarily to bring experts up to date as to the latest developments, analyze the significance of these developments, and to provoke suggestions as to underlying theories and profitable methods of approach for making new progress. No publications are prepared as emanating from the Conferences.

The morning sessions, Monday through Friday, are scheduled from 9:00 A.M. to 12:00 Noon, Eastern Daylight Saving Time. The second session each day is held in the evening from 8:30 to 10:00 P.M., Monday through Thursday.

Those interested in attending the Conferences are requested to send in their applications to the Director, on or before May 15, 1953. Each applicant must state the institution or company with which he is connected and the type of work in which he is most interested. Attendance at each Conference is limited to 100. Communications should be addressed to W. George Parks, Director, Department of Chemistry, University of Rhode Island, Kingston, Rhode Island. From June 15 to September 1, 1953, mail should be addressed to Colby Junior College, New London, New Hampshire.

Shown below are the programs for 1953 Chemistry and Physics of Metals Conference, and the Corrosion Conference.

Chemistry and Physics of Metals

July 13—Band Theory, Crystal Structure, and Phases.
July 14—Modification of Bands by Aperiodic Structures.
July 15—Transition Elements.
July 16—Optical Properties.
July 17—Ferromagnetism.

A Critical Review of Modern Fundamental Concepts in Corrosion

July 20—Thermodynamics in Corrosion; Electrochemical Theory of Corrosion.
July 21—Chemical Kinetics in Corrosion; High Temperature Oxidation.
July 22—Reaction Mechanisms: Intergranular Corrosion, Stress Corrosion, Pitting Corrosion, Fretting Corrosion.
July 23—Reaction Mechanisms: Corrosion Fatigue, Thermogalvanic Corrosion; Corrosion in Fused Salts and Molten Metals.
July 24—Corrosion in Non-Electrolytes.

New Nickel-Plating Process Offers Wide Use

The availability of an entirely new process of nickel plating which greatly stretches the available nickel supply, and which "may well prove to be one of the most far-reaching industrial developments since World War II" was announced recently by William J. Stebler, Executive Vice-President of General American Transportation Corporation, Chicago. General American will immediately build two new plants, one in East Chicago, Indiana, and the other in Los Angeles, California, to utilize the new process. These plants are expected to be in operation by the third quarter of 1953. Thereafter, other firms will be licensed to use the process.

The new process, named "Kanigen," requires no electrolytic equipment. It promises marked economies in many applications over customary methods, and makes it possible to plate almost any solid substance with a dependable and predictable thickness of a superior, nonporous plates.

The process, it is claimed, will plate any article uniformly, regardless of size or shape, and has proved satisfactory for the production-line plating of steel, copper, brass, bronze, stainless steel, and aluminum. Tests on plastics and magnesium indicate that these materials will prove practical for "Kanigen" plating.

Because of its greater efficiency, it is said the new process will provide important savings in critical nickel, requiring about ⅓ to ½ the nickel used with other processes. Reasons given are "Kanigen's" nonporosity, uniform plating, and because it takes 2 or 3 times more nickel to provide the same corrosion resistance with the electroplating process.

General American originally set out to develop a process for the interior coating of tank cars to carry corrosive chemicals and materials which must not be contaminated by "pick-up iron" from the tank car metal. The "Kanigen" process, developed through the reduction of nickel by the use of hypophosphites, resulted. A pilot plant was built in the summer of 1952 and has been in service since.

Since neither design nor size offers any complications to the "Kanigen" pro-

cess, and because of the hardness of "Kanigen" plate, large vessels, tanks, chemical process equipment, valves, pipe structures, and similar objects can be fabricated of any desirable and easily worked material, assembled, and then given a continuous coating of nickel in whatever thickness is desired. At present this thickness may be controlled when desired to within 1/10,000ths of an inch.

Westinghouse Forms Atomic Equipment Dept.

Westinghouse Electric Corporation, Pittsburgh, has announced plans for a multi-million dollar plant to produce atomic equipment. The plant will be operated by a newly formed department in its Atomic Power Division—the Atomic Equipment Department.

The new facility, which is believed to be the first major enterprise of its kind, will be located in Hamar Township, near Pittsburgh. Purpose of the department will be to engineer, manufacture, and sell products that have been developed for atomic power plants.

Uses Wanted for Gallium—"Wonder Metal"

The "use-wanted" sign is still out for gallium, one of the most unusual performers in the family of metals. The Aluminum Company of America, a major gallium producer, widely publicized its properties more than two years ago; yet only a few minor uses have developed.

To the researcher, the attraction of any rare material, for which no significant use has been found, is great. And, should its properties be unique, its attraction to the laboratory becomes almost magnetic. Gallium is one of these. It melts at about 86°F, but doesn't boil until 3600°F or higher. Like water, it expands upon solidification. It shows marked differences in electrical resistivity and coefficient of thermal expansion along the direction of the three axes of its crystallographic structure. Its electrical resistivity variability is believed greater than for any other metal. It emits electrons at extremely low temperatures. Thus, combining its unique properties, gallium is truly one of the most unusual elements.

Exploiting the properties of gallium has been the problem. Some uses are: In dental alloys for gold restoration work, where it reduces the melting point, increases strength and ductility, and displays other advantages. It has some application as an excitant for phosphors in fluorescent lighting and luminous paint. A patent has been issued for minor use in selenium rectifiers. Gallium chloride is used experimentally as a catalyst for polymerization of vinyl ethers. Radioactive gallium has been used in the diagnosis and treatment of bone cancer. In spyrochete-caused disease it has definite preventive and curative action. The most promising application, though quantitatively minor, is as a liquid seal on the inlet system of mass spectrometers, where its liquid range and low vapor pressure make it superior to mercury in analyzing hydrocarbons with high boiling points.

Despite this list of applications, the pounds of gallium so far used commercially in any year could be counted off on one's fingers—and it is over $1000 a pound.

Many other applications have been attempted or suggested. If there were a market the price could be lower; if the price were lower a market could be found. At any rate, Alcoa still seeks uses for the weird and wonderful enigma of the metallic world.

Armour Research Forms Safety Research Group

Armour Research Foundation of Illinois Institute of Technology, Chicago, has organized a fire protection and safety research group especially for service to Midwest industry.

The objectives of the group are: (1) to prevent fire or explosions from starting; (2) to limit the spread of fire after it has started; (3) to provide for prompt detection of fires; (4) to provide for prompt extinguishment; and (5) to prevent accidents.

Auromet Corp., New Firm Announced

C. B. F. Young and Nathaniel F. Crisera, in cooperation with Victor G. Gottlieb and David Neustadt, have announced the formation of a new company to be known as Auromet Corporation, with offices and laboratory located at 267 Elizabeth Street, New York, N. Y.

Auromet Corporation will manufacture precious metal solutions and salts. The corporation will give particular attention to the electronics field and has developed platinum and palladium solutions which can be used to deposit very thin films of these metals on electronic parts. This will be of interest to electronic engineers engaged in this work. Also emphasized is the refining of scrap metals and solutions.

A complete service will be available by the experienced personnel of the company who were formerly connected with A. Robinson & Son, New York, in the field of electrodepositing gold, silver, platinum, palladium, and rhodium.

Trade Notes

Nuclear-Chicago

Nuclear Instrument & Chemical Corporation, Chicago, will be identified in future advertising and sales promotion as "Nuclear-Chicago," according to an announcement by the president. This step was taken because of the large number of firms having names similar to the corporate title, which has in some instances, caused confusion among users of the company's products.

Dow Chemical Company

The Dow Chemical Company has entered into a contract with the Lehigh Warehouse & Transportation Company, Elizabeth, operator of public warehouses at Elizabeth, N. J., for the use of a 3¼ million gallon tank storage to be built at Bayonne, N. J. Lehigh expects to start construction about May and most of the facilities are expected to be ready for operation in September.

Norton Company

The New York City domestic sales offices of the Abrasive Division, Grinding Machine Division, and Refractories Division of Norton Company, Worcester, Mass., formerly of 61 Broadway, have moved to Green and North Sts., Teterboro, N. J.

The office of Norton Behr-Manning Overseas Inc., will remain at 61 Broadway, New York, N. Y.

Lindberg Engineering Company

Lindberg Engineering Company of Chicago, Ill., has announced the opening of a new West Coast plant at Downey, Calif.

Hammel-Dahl Company

The Hammel-Dahl Company of Providence, R. I., manufacturers of Automatic Control Equipment, announced the opening of two California offices to be devoted to sales and service of Hammel-Dahl products. The Los Angeles office is at 3715 Santa Fe Avenue and the San Francisco office is at 6 Market Street.

Winners of Cleveland Section Contest

For the second year, the Cleveland section of The Electrochemical Society sponsored a contest among ten colleges in the Cleveland area, with a view to increasing interest in the study of electrochemistry. The candidates for the contest were nominated by the heads of the chemistry departments of their respective colleges and the winners

NORMAN CRAIG

were chosen on the basis of their scholastic achievements as well as their interest in electrochemistry. Each will receive a one-year Student Associate Membership including a subscription to the JOURNAL of The Electrochemical Society.

The awards this year were made to Norman Craig of Oberlin College and Keith Coultrap of the University of Akron, and were presented by G. W. Heise, Chairman of the Contest Committee.

Norman Craig is a senior at Oberlin College with a rating for excellent

KEITH H. COULTRAP

scholarship in his freshman, sophmore, and junior years. He was elected to Phi Beta Kappa in his junior year. He has been a member of the College Faculty-Student Conference Committee and is president of the senior class. He plans graduate work in physical chemistry and has been awarded graduate assistantships in chemistry at two nationally known universities to which he applied.

Keith H. Coultrap served in the U. S. Army, Corp of Engineers, after graduation from high school in 1943. He entered the University of Akron in February 1946, and will be graduated with a B.S. degree in chemistry in June 1953. During part of this time he has been employed as a control and laboratory technician and, currently, as a chemist in production and technical control. He is a member of a number of fraternities and was president of Akron Colony in 1952. He is married and has two children.

SECTION NEWS

Chicago Section

"The Chemistry of Semiconductors and Transistors" was the subject discussed by Gordon K. Teal, Director of Materials Research, Texas Instruments, Inc., at the February 6 meeting of the Chicago Section.

Dr. Teal made an excellent presentation of the methods of preparing transistors of various types, discussing in particular detail in the growth of single crystals from molten germanium.

After discussing the characteristics of the various types of transistors, he demonstrated these characteristics on an oscilloscope. In addition to these demonstrations of theory, Dr. Teal showed the audience a transistor oscillator which he obtained on a galvanic cell made from a coin and using saliva as the electrolyte. This oscillator produced a signal which could be heard throughout the meeting room. Another interesting exhibit was a transistor amplifier.

Dr. Teal left his audience most eagerly awaiting the availability of transistors for nondefense application.

R. R. BANKS, *Secretary*

Cleveland Section

The March 10 meeting of the Cleveland Section was "local talent" night. Two speakers were invited to address the gathering: Richard S. Johnson, National Carbon Company, Cleveland, and John M. Finn, Jr., Horizons, Inc., Cleveland, both of whom discussed the investigations which led to their Ph.D. degrees.

Dr. Johnson, speaking on the subject "The Electrical Potential of the Manganese Dioxide Electrode," discussed the factors which determine the potential of the MnO_2 electrode. The application to dry cells was stressed. He showed that *p*H was not the sole effector in cells but that the activity of the NHy^+ ion is also a factor. Dr. Finn spoke on "The Electrolysis of the Alkali Metal Phosphides in Liquid Ammonia." He discussed the anode reactions of the phosphide anion in liquid ammonia.

The presentation of the Cleveland Section's Student Membership Awards was an added feature of the evening. This is reported in another column of the JOURNAL.

J. M. MARGOLIS, *Secretary*

New York Metropolitan Section

J. N. Mrgudich of the Signal Corps Engineering Laboratory, Fort Monmouth, New Jersey, spoke on the subject "Dry Battery Theory and Practice" at the New York Section meeting on March 4. Copies of the address were distributed and Dr. Mrgudich said he believed that this talk could be the basis for a paper for the Battery Manual, which he hopes the Battery Division may soom compile. A brief summary follows.

Theoretically, the speaker said, any oxidation-reduction reaction might be used to furnish an electric current, but, practically, only a few such reactions have been utilized. The familiar Leclanché cell is the most important commercially and it should be worth while to consider certain facts of its technology which have not been clearly described in the literature. Fundamentally, this cell consists of two electrodes separated by an electrolyte of ammonium and zinc chlorides. The positive electrode is manganese dioxide and the negative is metallic zinc. Zinc in contact with an aqueous solution tends to go into solution with the release of two electrons,

$$Zn \rightarrow Zn^{++} + 2e.$$

This reaction can proceed to the right only if provisions are made to remove both zinc ions and electrons. The solution acts as an electronic insulator, so electrons can move only if an external circuit is closed. Ions move by diffusion through the electrolyte. The magnanese dioxide functions as an absorbent for both electrons and ions,

$$2MnO_2 + 2e + Zn^{++} \rightarrow Mn_2O_3ZnO.$$

Dr. Mrgudich went on to discuss the

function and preparation of the components of the cell and pointed out that the depolarizing mix is the most complex and least understood part. A description of manufacturing and test procedures was given.

In conclusion, the speaker stated that it was the electrochemist's goal to produce electrical power directly from chemical reaction, but one of the problems which must be solved is the manner in which power can be generated at a sufficiently high potential. The silver iodide cell in which a number of cells can be assembled very compactly may point the way to a solution.

KENNETH B. MCCAIN

Niagara Falls Section

The Niagara Falls Section met on March 11 at the Red Coach Inn, Niagara Falls, New York. Twenty-six members and guests attended the dinner and thirty-five were present at the meeting following.

In a short business meeting the following officers for the 1953–1954 season were unanimously elected:

Chairman—Harry R. Oswald, Oldbury Electrochemical Company

Vice-Chairman—Warren D. Sherrow, Great Lakes Carbon Corporation

Secretary-Treasurer—John E. Currey, Hooker Electrochemical Company

The speaker of the evening was Malcolm F. Judkins, New Products Manager, Firth-Sterling, Inc., Pittsburgh, who spoke on the subject "Electromechanical Machining by Method X." This very interesting method, Mr. Judkins said, uses electrical energy directly for the machining and the "tool," which is a hollow electrode that does not touch the work, can be almost any conducting material and may be much softer mechanically than the material machined. Thus a hole can be drilled in tungsten carbide (Rockwell Hardness C78) with a brass "tool."

The principle of the method, the speaker stated, is in essence the generation between the work and the electrode of a magnetic field of force which exceeds the tensile strength of the work.

MALCOLM F. JUDKINS

Thus with a 50-volt power source, a force of 310,000 lb/in.^{2} can be attained. The work is submerged in a dielectric such as kerosense and the kerosene is forced through the hollow electrode. The latter is automatically lowered to provide a constant spacing from the work, and cutting rates of several inches per minute have recently been achieved. Advantages of the method include permitting the machining of very hard materials, of sections too thin or weak for customary methods, and the attainment of very close tolerances. Threaded 3/8-inch blind holes have been machined in tungsten carbide.

The equipment for the work is leased by Firth-Sterling, Inc., and rights have recently been sold to Excell Machine Company, Detroit, Michigan.

Mr. Judkins demonstrated the method with a portable unit, cutting the letter "C" through a 1/8-inch thick piece of tungsten carbide in about five minutes.

MILTON JANES, *Secretary-Treasurer*

Philadelphia Section

The Philadelphia Section held its third meeting of the current season on March 4 in the John Harrison Laboratory of Chemistry of the University of Pennsylvania. Sixty or seventy persons in attendance heard the President of The Electrochemical Society, Dr. J. C. Warner, lecture on the history of theories of electrolytes. Dr. Warner is the president of Carnegie Institute of Technology.

Prior to the meeting, members and guests of the Section had the privilege of meeting Dr. Warner at an enjoyable informal dinner held at the Lenape Club, on the University campus. The occasion also offered a pleasant opportunity for Dr. Warner's old friends in the Philadelphia area to renew acquaintanceships.

Chairman John F. Gall presided at the meeting. Dr. Hiram Lukens reported for the nominating committee, comprising also Dr. Arthur Osol and Mr. Homer Cherry, on the committee choice of candidates for officers of the Philadelphia Section, to be voted on at the May meeting. The committee nominated the following persons, at the same

MANUSCRIPTS AND ABSTRACTS FOR FALL MEETING

Manuscripts are now being received for the Fall Meeting of the Society, to be held at the Ocean Terrace Hotel in Wrightsville Beach, N. C., September 13, 14, 15, 16, and 17, 1953. Subjects to be covered at the technical sessions will be Battery, Corrosion, and Electrodeposition.

To be considered for this meeting, triplicate copies of manuscripts or abstracts (not to exceed 75 words in length) must be received at Society headquarters, 235 West 102nd Street, New York 25, N. Y., *not later than July 1, 1953.*

time mentioning that candidates could be added to this slate by the membership prior to the May meeting:

Chairman—J. Fred Hazel
Vice-Chairman—Edgar L. Eckfeldt
Treasurer—G. Franklin Temple
Secretary—George W. Bodamer

Dr. Hazel reported on the plans for the May meeting of the Section to which the ladies are especially invited. Following the business meeting, Dr. Lukens presented Dr. Warner to the gathering.

Dr. Warner began his talk with comments on the present status of our Society. The Philadelphia Section was very glad to hear that the Society is in a more favorable position than it has been in for the last five or six years.

Dr. Warner next discussed the theories of electrolytic solutions, tracing them from the time when the distinction between electrolytes and nonelectrolytes was first recognized, to the present day. The successes and failures of the Arrhenius theory were outlined. This was followed by reference to the achievements of those who systematically studied the thermodynamic properties and conductance of electrolytes. Finally, the modern theories of Debye, Hückel, Milner, and Onsager to explain the physical properties and conductance of electrolytes were outlined.

Dr. Warner answered questions from the audience. In appreciation to the speaker, the Philadelphia Section closed the meeting with a rising vote of thanks.

EDGAR L. ECKFELDT, *Secretary*

PERSONALS

RICHARD GLICKSMAN has accepted a position with Radio Corporation of America, RCA Laboratories Division, Princeton, N. J. Mr. Glicksman was formerly a teaching fellow at New York University, New York City.

ANDREW C. HOLM of Shawinigan Chemicals Ltd., Shawinigan Falls, Quebec, was recently appointed a Regional Editor on the JOURNAL for Canada. The current extensive developments in Canada should prove of interest to JOURNAL readers.

ARTHUR A. WINTERBOTTOM has accepted an assignment in Pakistan under the auspices of UNESCO, and will be located at UNESCO T. A. Mission, Department of Metallurgy, University of Dacca, Dacca, East Pakistan. Professor Winterbottom had been at the Metallurgical Institute, Trondheim, Norway.

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W. C. VOSBURGH, Department of Chemistry, Duke University, Durham, N. C., has been appointed editor of the Battery Division of the JOURNAL, succeeding former Battery Editor N. C. CAHOON.

LOWELL A. WOODBURY, Department of Physiology, University of Utah, Salt Lake City, has recently joined the Atomic Bomb Casualty Commission.

MICHAEL J. PRYOR has left the Division of Applied Chemistry, National Research Laboratories, Ottawa, Canada, to join the Corrosion Laboratories, Division of Metallurgical Research, Kaiser Aluminum & Chemical Corporation, Spokane, Wash.

L. D. THOMAS has joined the Libbey-Owens-Ford Glass Company, Toledo, Ohio. Mr. Thomas was previously studying at the University of Michigan, Ann Arbor, Mich.

ALLEN S. RUSSELL has been appointed chief of the Physical Chemistry Division, Aluminum Research Laboratories, New Kensington, Pa., succeeding CYRIL STEAD TAYLOR who retired on March 1. Dr. Allen served as assistant Division Chief since 1946.

JOHN B. MERRILL has been appointed to the newly created post of vice-president in charge of Metallurgical and Chemical Operations at Sylvania Electric Products Inc. A vice-president of the company since 1951, Mr. Merrill now has responsibility for Sylvania's Atomic Energy Division, in addition to retaining executive direction of the Tungsten and Chemical Division.

M. MERLUB-SOBEL has accepted a position as research specialist at Horizons, Incorporated, Cleveland, Ohio. Mr. Merlub-Sobel had been at the Hebrew Institute of Technology, Haifa, Israel, and more recently was located in Jersey City, N. J.

G. G. CREWSON, formerly chief engineer, has been named Director of Engineering at Buffalo Electro-Chemical Company, Inc., Buffalo, N. Y.

Mention the Journal

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NEW MEMBERS

In March 1953, the following were elected to membership in The Electrochemical Society:

Active Members

JOHN C. CESSNA, National Carbon Research Laboratory, mailing add: 1291 Lakeland Ave., Cleveland, Ohio (Corrosion)

S. L. CHAWLA, Delhi Polytechnic, Applied Science Department, Delhi, India (Industrial Electrolytic)

HAROLD E. DAVID, D & M Alloy Company, Box 342, Rahway, N. J. (Electrothermic)

FERDINAND P. HELLER, American Chemical Paint Company, Ambler, Pa. (Corrosion)

JAMES O. KOEHLER, National Carbon Company, mailing add: 8314 Deerfield Dr., Parma, Ohio (Electro-Organic)

CLIFFORD M. TUBB, Associated Ethyl Company, Ltd. Oil Sites Rd., Ellesmere Port, Cheshire, England (Industrial Electrolytic)

ROBERT W. WOLLENTIN, Westinghouse Electric Corporation, Mailing add: 75 Martin St., Bloomfield, N. J. (Electronics)

JOHN F. YEAGER, National Carbon Company, 2034 Cornell Road, Cleveland, Ohio (Battery, Electrodeposition, and Theoretical Electrochemistry)

Reinstatement

ANDREW C. HOLM, Shawinigan Chemicals Limited, P.O. Box 330, Shawinigan Falls, Quebec, Canada (Electrodeposition and Electrothermic)

Associate Member

BALDEV K. SARDANA, D.C.M. Chemical Works, Post Box 1211, Delhi, India (Industrial Electrolytic)

Student Associate Members

KEITH H. COULTRAP, University of Akron, mailing add: 1799 Ninth St., Akron, Ohio (Electro-Organic)

NORMAN C. CRAIG, Oberlin College, mailing address: 6515 Barnaby St., Washington, D. C. (Theoretical Electrochemistry)

DEMETRIUS N. TRIADIS, Massachusetts Institute of Technology, Room 8–206, Cambridge, Mass. (Corrosion)

WILLIAM H. WADE, University of Texas, Brackenridge Hall, Room 125, Austin, Texas (Theoretical Electrochemistry)

ANNOUNCEMENTS FROM PUBLISHERS

SOLUBLE SILICATES, 2 volumes, by James G. Vail. American Chemical Society Monograph No. 116. Published by Reinhold Publishing Corporation, New York, 1953. Volume I, 370 pages; Volume II, 600 pages.

This comprehensive work deals with the history, theory, and application of the soluble silicates.

THE DESIGN OF A PHOSPHATE SMELTING FURNACE by Harry A. Curtis. Published by the Tennessee Valley Authority, Knoxville, as Chemical Engineering Bulletin No. 1. October 1952.

PRINCIPIOS DE ELECTROQUÍMICA. EXPERIMENTAL Y TEORICA, Spanish translation by Jesus Nicolas of Malcolm Dole's book "Experimental and Theoretical Electrochemistry." Published by Editorial Alhambra, Madrid, Spain, 1952.

1950–51 JOURNAL ELECTRODEPOSITORS' TECHNICAL SOCIETY, Volume 27. Published by the Institute of Metal Finishing, London, England, 1952.

This volume covers the proceedings of the Institute of Metal Finishing for Session 26.

VACUUM TUBE OSCILLATORS by William E. Edson. Published by John Wiley & Sons, Inc., New York, 1953. 476 pages, $7.50.

This book covers every phase of vacuum tube oscillator activity and phenomena and offers the latest information on oscillator design and analysis.

TUNGSTEN—ITS METALLURGY, PROPERTIES AND APPLICATIONS by Colin J. Smithells. Published by The Chemical Publishing Company, Inc., New York, 1953. 326 pages, plus 74 pages of illustrations, $8.50.

This is a comprehensive volume on the metallurgy, chemical and physical properties, and industrial applications of tungsten.

"Electrochemistry in the Pacific Northwest"

will appear in an early issue of the JOURNAL—one of the series of Regional Features.

NEW PRODUCTS

INEXPENSIVE MICROMANIPULATOR. New micromanipulator of the rack and pinion type for rapid manipulation is available for under $100. Has two inches of travel in three planes; tool holder accommodates small hand vise or special tools, glass tubing, or rods. Handles Benedetti-Pischler techniques requiring precision transfer of small volumes of inorganic compounds. Microchemical Specialties Co. N-1

ULTRASONIC CLEANING. An advanced, practical method of metal cleaning through the use of ultrasonic waves, known as the Detrex Soniclean Process, features a man-made element for directing sound energy. The new element, in place of quartz crystals previously used, overcomes limitations caused by size and properties of quartz. Detrex Corp. N-2

NEW SENSITROL RELAY. New relay of the Sensitrol (magnetic contact) type, Model 723, is sealed against moisture and incorporates a newly designed, self-shielded core magnet mechanism and a built-in solenoid release device. Supplied in a variety of ranges with double magnetic contacts, or with single magnetic contacts to make contact on either increasing or decreasing values. Sensitivities as high as 2-0-2 microamperes are available, and both a-c and d-c voltage ranges can be supplied self-contained up to 500 volts, the company says. Weston Electrical Instrument Corp. N-3

ELECTRONIC LIQUID LEVEL CONTROL. The new Belmont Level Control provides adjustment of liquid level and cut-in, cut-out differential over very wide limits, based on capacitive action of liquid surrounding a porcelain-enamel-covered-electrode. In operation, the new unit consists of the probe, mounted directly at the location of the controlled liquid, a connecting cable which can be 1000 feet long if necessary, and the control unit which can thus be located for operating convenience. Thermo Instruments Co. N-4

TUNGSTEN ALLOY FOR INERT GAS WELDING. A new tungsten zirconium alloy arc-welding rod that saves time and expense on inert gas welding jobs has been announced. Called Zirtung, the new electrode features less contamination pickup on touch starting, continued steady arc, and longer working life. Ideal for use on all metals, particularly mild steel, aluminum, and magnesium. Sylvania Electric Products Inc. N-5

NEW ROSIN CORE SOLDER. A new rosin core solder, active yet noncorrosive, has recently been developed. Known as RTS 200, it has been proved in production operations to have many advantages over ordinary rosin solders; 30% greater spread, pierces retarding agents four times faster, the flux is just as active after standing for long periods. Federated Metals Division, American Smelting and Refining Co. N-6

VOLTAGE REGULATED POWER SUPPLY. The new Kepco Model #1520 features a regulated high voltage d-c power supply with excellent regulation, low ripple content, and low output impedance. The high voltage supply

is continuously variable from 0–1500 volts and delivers from 0–200 milliamperes. Ripple voltage is less than 30 millivolts peak to peak. Kepco Laboratories, Inc. N-7

Members: Please Check Your Code Numbers

Code numbers appear at the right of your name and address on mail from the Society office. For instance, 6 means Active Member, New York Section, Corrosion Division.

A complete explanation of the code is printed below. In order to keep the records up to date, members are kindly requested to check the code numbers on recent mail from the Society and, if incorrect, please send the corrected code number to The Electrochemical Society, Inc., 235 West 102nd Street, New York 25, N. Y.

Membership Classifications	*SECTIONS* *No.* *City*	*Division Classification*
1 Active Member	1 Chicago	A Battery
2 Honorary	2 Cleveland	B Corrosion
3 Sustaining	3 Detroit	C Electric Insulation
4 Associate Member	4 India	D Electrodeposition
5 Student Associate	5 Midland	E Electronics
6 Subscriber	6 New York	F Electro-Organic
	7 Niagara Falls	G Electrothermic
	8 Pacific Northwest	H Industrial Electrolytic
	9 Philadelphia	I Theoretical Electrochemistry
	10 Pittsburgh	
	11 San Francisco	
	12 Washington-Baltimore	
	— No Section	

LITERATURE FROM INDUSTRY

ELECTRONIC WATTMETER. New 2-page bulletin describes Keithley Model 110 Electronic Wattmeter. Includes complete specifications and full description of features, which include a range of 0.3 to 9000 watts, 20 to 3000 cps response, unusual convenience and accuracy in measuring low impedance devices. Keithley Instruments. P-130

HANDBOOK FOR CHEMISTRY ASSISTANTS is a unique 32-page manual prepared and published by the Division of Chemical Education of the American Chemical Society. Designed for use by graduate and undergraduate student

assistants; easy-to-read chapters on Conducting A Recitation Period; Conducting A Laboratory Period; Quizzes, Tests, Reports, etc. Fisher Scientific Co., Educational Service Dept. P-131

VACUUM TUBE ELECTROMETERS are described in a new 8-page bulletin. Nineteen application diagrams are included, plus a full description of accessories, which permit measuring a wide range of d-c voltages, currents as low as 10^{-14} ampere, resistance to 10^{16} ohms. Keithley Instruments. P-132

CORROSION-PROOF STRUCTURAL PLASTIC. Complete engineering facts, including information on fabrication and design factors, physical strength and chemical resistance of unplasticized, rigid polyvinyl chloride Ampcoflex are provided in new illustrated bulletin. Includes chart showing resistance characteristics and detailed tabulation of physical properties. Atlas Mineral Products Co. P-133

PHOTOELECTRIC RECORDER APPLICATIONS. Fully illustrated 12-page publication describes applications of the recorder with seismology, psychology, textile, metals, fatigue and research testing equipment, as an aid in the quick detection of pipeline corrosion, and in development and machinability testing, medical research, light-intensity study, etc. General Electric Co. P-134

To receive further information on any New Product or Literature from Industry listed above, send inquiry, with key number, to JOURNAL of The Electrochemical Society, 235 West 102nd Street, New York 25, N. Y.

Please print your name and address plainly.

RECENT PATENTS

Selected for electrochemists by Fred W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

November 25, 1952

Aukerman, N. B., Ingram, S. A., executrix of said Aukerman, N. B., deceased, 2,619,456, Metal Recovery Apparatus

Wagner, F. W., 2,619,457, Electroplating Anode

ADVERTISERS' INDEX

Bell Telephone Laboratories . 112C

Enthone, Incorporated . . . Cover 4

General Chemical Division, Allied Chemical & Dye . . . 123C

Great Lakes Carbon Corporation . . . . . Cover 2

Lindberg Engineering Company 116C

Rapid Electric Company 131C

Ronal Chemicals, Inc. . . . . Cover 3

E. H. Sargent & Company . . 115C

January 27, 1953

Smith, A. W., 2,626,620, Regulator Responsive to the Electrical Conductivity of a Solution

Balke, C. W., 2,626,895, Electrolytic Production of Iron

Hunrath, G., 2,626,970, Thermoelectric Couple and Method of Making Same

FUTURE MEETINGS OF
The Electrochemical Society

* * *

Wrightsville Beach, N. C., September 13, 14, 15, 16, and 17, 1953

Headquarters at the Ocean Terrace Hotel

Sessions on

Battery, Corrossion, Electrodeposition

* * *

Chicago, May 2, 3, 4, 5, and 6, 1954

Headquarters at the La Salle Hotel

Highlights of the Board of Directors' Meeting

(Held January 30, 1953)

For the first time in several years, the Society operated in the black during the year 1952. The audit indicates an excess of income over expenditures of $2,460.72, as shown in the Auditor's Report below.

The budget for the year 1953 was approved. In this budget the amount of $26,000 was approved for printing and mailing of the JOURNAL. This is a $2,000 increase over the previous year. The estimated income from advertising, $11,878, was that amount of advertising contracted for by January 30. A provision was made whereby the budget for the printing and mailing of the JOURNAL would be automatically increased 50 per cent of any additional advertising income. The remaining 50 per cent would go to building up Society reserves. It is interesting to note that the budget, as approved for 1953, anticipates an excess of income over expenditures of $383, while the budget for 1952, as revised in June 1952, indicated a deficit of $1,130, whereas the audit shows that we operated well in the black. Therefore, it is a much more optomistic financial picture that we are now presenting.

It was decided that, in order to make the business affairs of the Society more readily available to the local sections, copies of the minutes of the meetings would be distributed to the chairmen and secretary-treasurers of each local section.

The future meetings of the Society were discussed, and these are scheduled as follows:

New York—Spring 1953
Wrightsville Beach—Fall 1953
Chicago—Spring 1954
Boston—Fall 1954
Cincinnati—Spring 1955
Pittsburgh—Fall 1955
San Francisco—Spring 1956

HENRY B. LINFORD, *Secretary*

Auditor's Report

BALANCE SHEET

December 31, 1952

Assets		
Furniture and Office Equipment	$ 4,274.03	
Cash	14,823.31	(a)
U. S. Savings Bonds (Cost)	28,860.00	(b)
Inventory-Bound Volumes	2,691.60	
Accrued Income on Investments	5,226.00	
Accounts Receivable	184.50	
	$56,059.44	
Liabilities, Reserves and Surplus		
Accounts Payable—Suppliers	$ 4,918.12	
Taxes Withheld From Salaries	520.50	
Life Memberships	1,443.50	
Prepaid Sustaining Memberships	800.00	
Prepaid Subscriptions	4,367.20	
Reserve for Depreciation	625.79	
Deferred Income (India Section)	.70	
Surplus	43,383.63	
	$56,059.44	

(a) Includes $3,265.63 Corrosion Division funds.
(b) Includes $10,471.37 Corrosion Division funds.

CASH STATEMENT

January 1 to December 31, 1952

National City Bank		
Book balance December 31, 1951		$8,401.81
Receipts—1952 (Gross)	$77,182.82	
Disbursements—1952 (Gross)	76,389.43	
Excess receipts over disbursements		793.39
Book balance December 31, 1952		9,195.20
New York Savings Bank		
Book balance December 31, 1951		1,918.68
Interest 1952		50.93
Transferred from National City Bank	1,787.40	
Transferred to National City Bank	491.38	
Excess of transfers in		1,296.02
Book balance December 31, 1952		3,265.63
Corn Exchange Bank Trust Company		
Book balance December 31, 1951		2,117.65
Receipts—1952 (Gross)	35,476.04	
Disbursements—1952 (Gross)	35,279.44	
Excess receipts over disbursements		196.60
Book balance December 31, 1952		2,314.25
Cash on hand—Agent—December 31, 1952		48.23
Total		$14,823.31
Total accounted for as follows:		
National City Bank per bank statement		9,195.20
New York Savings Bank per bank statement		3,265.63
Corn Exchange Bank per bank statement	2,858.61	
Less outstanding checks	544.36	2,314.25
Cash on hand—Agent		48.23
Total, as above		$14,823.31

ANALYSIS OF EXPENDITURES

January 1 to December 31, 1952

Furniture and Office Equipment		$ 47.54
Publication Department		
General Expenses		
Salaries, full-time employees	$10,800.50	
Wages, part-time employees	64.00	
Rent	810.00	
Stationery and supplies	635.84	
Postage and express	650.36	
Traveling	197.86	
Miscellaneous office expenses	593.42	13,751.98

Publication Expenses		
Journal	27,057.59	
Reprints	2,114.35	29,171.94
Secretary's Department		
Salaries, full-time employees	16,114.91	
Wages, part-time employees	303.50	
Rent	810.00	
Stationery and supplies	831.23	
Postage and express	1,129.97	
Traveling	512.62	
Miscellaneous office expenses	590.90	
Audit	175.00	
Prizes	100.00	
Local Sections:		
Philadelphia	131.50	
Cleveland	129.00	
N. Y. Metropolitan	256.00	
Midland	68.00	
India	136.50	
Wash.-Baltimore	24.00	
Pittsburgh	50.00	
Publication Committee	185.71	
Corrosion Division	491.38	
Conventions	1,482.82	
Emblems	45.34	
Advertising	4,532.21	
Sale of Publications	208.65	
Surplus (1951 and 1952 Faraday)	2,096.84	30,406.08
		$73,377.54

Analysis of Income

January 1 to December 31, 1952

Dues:	
1948	$ 6.00
1949	10.00
1950	6.00
1951	205.00
1952	9,177.33
1953	18,527.89
Volumes:	
1952	18.00
1953	1,494.10
Publications	2,343.39
Nonmember subscriptions—Journal	14,280.78
Advertising	9,966.99
Conventions	2,691.86
Preprints	132.10
Reprints	2,731.86
Emblems	95.00
Thompson Monograph	21.10
Membership Directory	225.50
Sustaining Memberships	8,150.00
Bank Interest	50.93
Cathodic Protection	385.55
Canadian Convention Fund	1,135.40
Modern Electroplating	476.05
Journal	1,920.03
Corrosion Division	1,787.40
	75,838.26
Excess income over expenditures	$ 2,460.72

Accounted for as follows:

Surplus (increase)	$ 2,508.2
Less: Furniture and office equipment	47.5
	$ 2,460.7

(Signed) H. K. Leicht, Audit

Proposed Budget for 1953

Income

	Estimated Income 1953	Revised (June 1952 Budget for 19
Membership Dues	$33,000	$26,0
Sustaining Memberships	9,000	7,3
Sale of Publications		
Back Transactions & Journals	2,000	2,0
Reprints & Preprints	2,500	3,0
Non-member Journal subsciption	15,000	12,0
Office Sale of Journal	1,500	8
Modern Electroplating	50	4
Royalties Cathodic Protection	100	4
Convention Registration	2,000	1,3
Advertising	11,878*	10,0
Total Income	$77,028	$63,6

Expenditures

	Estimated Expenditures 1953	Revised (June 1952 Budget for 19
Printing and Mailing Journal	$26,000*	$24,0
Reprints	2,000	2,3
Publication Commission	250	2
Adv. Commission	5,200*	7
A.B.C. Rating	300	—
Salaries	33,000	27,6
Rent	1,620	1,6
Postage, Supplies & Misc.	4,800	4,3
Travel	700	7
Auditor	175	1
Loc. Sec. & Div.	1,000	1,0
Prize to Young Authors	100	1
Program Booklets, etc.	1,500	1,5
Total Expenditures	$76,645	$64,7
Total Income	77,028	63,6
Excess Income over Expenditures	$ 383	$ 1,1

* Advertising income is estimated at $11,128. This rep sents actual contracts in hand to date. There is good expectan that this item will increase markedly during the year. Sin advertising agent's commission is on the basis of a minim $5,200, this figure will remain fixed until such time as the it of advertising listed under Income reaches $20,800, at wh time our representative will receive 25% of our income fr advertising. Therefore, it must be considered automatic th our item of $5,200 will be the minimum. The maximum will based on the ultimate advertising income in case the inco exceeds $20,800. The proposed budget indicates an excess income over expenditures of $383. Further advertising inco above $12,000 will automatically increase the printing a mailing of the Journal budget by 50% of any additional adv tising income.

Technical Review

Review of Articles on Luminescence for 1951-1952[1]

Gorton R. Fonda[2]

New Phosphors

Phosphates.—Smith (1) found three crystalline forms of zinc orthophosphate and studied them under cathode-ray (CR) excitation. With low manganese, the normal form is stable at all firing temperatures and fluoresces at 5520 Å. Above 1 mole per cent Mn and above 800°C, another form of novel structure results which fluoresces at 6380 Å with 2½ times the luminescence energy. When prepared in the presence of magnesium or zinc orthophosphate, still another form results, with its emission at 6320 Å.

Froelich and Margolis (2) studied $Ca_3(PO_4)_2$:Ce:Mn, in which the cerium, whose emission peaks at 3600 Å, sensitizes the manganese emission at 6500 Å under excitation by 2537 Å. The crystalline form, stable above 1100°C, is brighter than the form found below 1100°C, but both have the same emission. In liquid air the manganese band decreases sharply and the cerium band increases two- to threefold, although a change in temperature has no effect with cerium alone. Under CR the phosphor emits red when prepared with excess base and yellow-orange with excess acid. Firing with sodium makes the phosphor sufficiently susceptible to 3650 Å at 300°–500°C that it acquires value as a color corrector for the high-pressure mercury lamp.

Additions have been made to the halophosphates. Ranby (3) describes activation of calcium fluophosphate by silver to give an emission band at 3200 Å to 4800 Å under 2537 Å, and to serve also to sensitize the manganese emission. Anderson and Wells (4) describe the halophosphates of magnesium and barium activated with uranium, silver, and thorium. With uranium, the barium compound gives a green emission. Under 3650 Å, it is comparable to ZnS:Cu; and under 2537 Å, to zinc silicate. Wollentin, Wei, and Nagy (5) modified McKeag's cadmium chlorphosphate by substituting chlorides of barium, strontium and magnesium plus zinc. The brightness and maintenance are inferior to the calcium halophosphates but their peak emission is extended to 5900 Å to 6080 Å.

Silicates.—Jenkins and McKeag (6) prepared silicates of the alkaline earths, activated with europium, whose emissive color varies with the mole ratio of metal oxide to silica. With a ratio of 2 to 3 the emission is green, and is shifted to the blue with decreasing ratio. They are most efficiently excited by 3650 Å to the brightness of zinc cadmium sulfides of the same emissive color. They describe also a calcium pyrophosphate activated with dysprosium, which is excited most strongly by CR and has brighter phosphorescence than zinc cadmium sulfide.

Double alumino-silicates of an alkaline metal combined with an alkaline earth and activated with copper have been studied by Claffy and Schulman (7). The brightest has the molar composition, $0.5Na_2O + 0.5CaO + 1.0Al_2O_3 + 6.0SiO_2 + 0.02Cu$; its emission has the same spectral distribution as unactivated calcium tungstate, with one half the brightness. Nagy, Wei, and Wollentin (8) synthesized a hardystonite, $Ca_2Zn(SiO_3)_3$, activated with lead. The introduction of zinc shifts the emission peak from 3350 Å to 3450 Å and yields a performance in lamps equal to Froelich's cerium-activated calcium phosphate.

Sulfides.—Prener (9) produced a zinc sulfide activated with arsenic which emits a red As band at 6200 Å in addition to the unactivated blue band. With high arsenic, a band appears at 5200 Å. The emission of the zinc oxide phosphor has been shifted to shorter wave lengths by solution in it of magnesium oxide, up to 25 mole per cent, as found by Smith (10). Magnesium has a similar effect in the zinc and zinc-cadmium sulfides activated with silver or copper. With copper there is a very long phosphorescence under CR.

Kroeger, Bril, and Dikhoff (11) found that a single component screen for TV can be prepared from the phosphor ZnCdS(Al):Ag:Au, which has the same ICI point as the usual mixture of two sulfides. In brightness, current saturation, and color change toward the yellow with increase in beam current, it is close to the usual mixture.

A zinc sulfide activated with 0.01–1.0 per cent Cu has been prepared by Froelich (12) in pure H_2S without oxide or chloride addition. The normal blue and green bands appear under 3650 Å and also a yellow band and a strong red band at 6500 Å to 6700 Å. All four bands respond moderately to electroluminescence. Under CR only the blue and green bands appear. When prepared similarly with aluminum equal to the copper content, a green band and one at 5800 Å are emitted under 3650 Å; it is not excited by CR nor under electroluminescence.

Miscellaneous.—Schulman, Ginther, and Klick (13) studied a sodium chloride activated with lead. Under excitation by 2730 Å, it emits at 3200 Å with low lead and at both 3200 Å and 3850 Å with high lead. With increase in temperature, the 3850 Å band decreases much faster than the 3200 Å, showing a similarity in this respect also to the manganese-activated zinc and calcium silicates. The phosphors are unstable. Phosphors of lead and manganese chlorides with potassium chloride have been prepared by Ginther (14), and their emission and complex excitation bands were measured. K_4MnCl_6:Pb emits at 6100 Å under 2537 Å, 2700 Å to 3000 Å, or 3650 Å. The manganese band is sensitized by thallium as well as by lead. A much weaker emission at 6300 Å is given by KCl:Mn:Pb.

Kroeger, Ouweltjes, and others (15) developed a phosphor discovered by Travnicek for color correction in the high-pressure mercury lamp by application to the outer bulb. It is a basic magnesium arsenate with six moles MgO to one mole As_2O_5, activated with quadrivalent manganese. Its emission includes five bands in the range 6200 Å to 6580 Å. Its quantum efficiency is 75 per cent under 2537 Å and 3650 Å. Its brightness remains constant to 500°C and then decreases rapidly as the decay constant rises. For good maintenance it must be operated in an oxygen atmosphere.

[1] This review covers the articles published since the last annual review, which appeared in the March 1951 JOURNAL, page 35*C*.

[2] Consultant, General Electric Company, 1028 Parkwood Boulevard, Schenectady, New York.

Kroeger, Vink, and Van den Bomgaard (16) found that magnesium oxide with nickel emits green luminescence under CR at liquid air temperature. Larach (17) prepared a complex phosphor, $Zn_2Nb_2Ta_2O_{11}$:Mn, which shows green luminescence under CR at an intensity which is 10 per cent of zinc silicate.

Phosphor Characteristics

Oxygen-dominated.—Several papers deal with zinc silicates. CR luminescence has been measured in a demountable tube for aluminized screens of different thickness by Larach and Shrader (18). The increase in brightness with applied voltage tends toward saturation at 2–6 mg/cm², but at 9 mg/cm² the results nearly fit the equation $L = KV^{0.8}$. Larach (19) repeated Anderson's and Wells' preparation of barium zinc silicate and confirmed its red emission under ultraviolet (UV). Under CR he finds its main band to be at 5300 Å, with a secondary at 6900 Å.

Vlam (20) measured the emission of zinc silicate with 0.1 per cent Mn at 15°K under 2537 Å. The photographed spectrum showed 19 lines, a few of which had been observed previously by Randall and by Shrader. Klick (21) repeated measurements on this phosphor and also on others, including $ZnWO_4$, KCl:Tl, ZnS:Cu, ZnS:Ag, CdS:Ag, and CdS at 77°K and at 4°K. Only those showing edge emission have a tendency to exhibit line emission. Those with activators showed no change below 100°K. Possible explanations involve interactions between excitons and the conduction level. The many lines found by Vlam were not confirmed.

The excitation spectra of various silicates, including both the green and yellow fluorescing zinc silicates, zinc beryllium silicate, calcium and barium silicates, and various tungstates, have been recorded by Oszy (22). The effect of change in temperature upon emission spectra and intensity has been determined by Jerome (23) for some of the current lamp phosphors, including calcium halophosphate, calcium silicate, zinc beryllium silicate, and magnesium tungstate. The CR luminescence of calcium sulfate activated by manganese has been studied by Watanabe (24).

Sulfides.—Bube (25) analyzed copper-activated zinc sulfides and confirmed Kroeger's conclusion that the chlorine content is a function of the copper concentration. He finds, however, that the mole ratio of chlorine to copper decreases with increase in copper content. He believes that the results are in accord with his previous conclusion that the green emission with low copper is due to interstitial ions of Cu^+ and that the blue emission with high copper is due to Cu^{++} ions substituted for zinc.

That oxygen may also be a coactivator as a substitute for chlorine has been shown by Kroeger and Dikhoff (26) for solutions of zinc oxide in zinc sulfide. It introduces a new absorption band and shifts the emission bands of copper, silver, and gold by 150 Å toward longer wave lengths. It fails to give the brightness attained with chlorine. When both chlorine and oxygen are present, the emission bands of each appear in a composite band whose peak is shifted only 100 Å from the band with chlorine alone. Oxygen increases the phosphorescence and introduces additional glow peaks. It is believed to be associated with the activator ions.

Related to this is the description by Verwey and Kroeger (27) of the method of "controlled valency," exemplified in semiconductors by the decomposition product formed at 1200°C from a mixture of nickel carbonate with a small amount of lithium carbonate. In the resulting nickel oxide there is thought to be enough trivalent nickel ions to compensate for the monovalent lithium ions present. The same consideration applies to zinc sulfide phosphors in which the presence of a monovalent activator finds compensation in the presence of an equivalent amount of monovalent halogen or of a trivalent cation. They believe that this mechanism is applicable to other phosphors.

Unexpected emission bands have been observed by Feldt and coworkers (28) in silver-activated zinc cadmium sulfide high in cadmium. Under CR the emission band with high silver was shifted to shorter wave lengths by increase in current density. Under UV at 77°K the apparent shift was resolved into two bands, one of which corresponded to the new band found under CR. It proved to be the silver band which is suppressed at 25°C. The other band was that normally observed in the unactivated phosphor.

Bube (29) measured the change in photoefficiency of copper-activated zinc sulfide as a function of temperature and copper content. He also determined the accompanying change in photoconductivity and concludes that its process is different from that of luminescence. Single crystals of zinc sulfide were grown by Piper (30) in evaporated quartz bulbs by vaporization at 1170°–1200°C, 5 mm long and 3 mm² in cross section. Johnson (31) gave a general survey of the preparation of phosphor single crystals.

Transparent screens of manganese-activated zinc sulfide have been prepared by Studer, Cusano, and Young (32) either (*a*) by passing a stream of zinc vapor containing a little manganese chloride vapor over a heated glass surface at a few mm pressure of H_2S, or (*b*) by first vaporizing a film of ZnF_2:Mn and then converting to ZnS:Mn by heating in H_2S. Transparent screens have also been prepared of zinc and zinc-cadmium sulfides with various activators.

By radioactive tracer study, Dreeben and Ward (33) determined the distribution of calcium, europium, and samarium between phosphor and flux melt in the preparation of the *IR* sensitive phosphor, (Ca, Sr)S:Eu:Sm. Brauer (34) studied the emission spectra of the sulfides and oxides of magnesium, strontium, calcium, and barium activated with europium. The europium proved to be trivalent in the oxides and divalent in the sulfides. Gobrecht and Hahn (35) studied the phosphors prepared without activators by variable reduction of alkaline sulfates. Their emission, quantum yield, and decay were measured under 3660 Å and 2540 Å at various temperatures. Red emission under 3660 Å is ascribed to polysulfide formation, and blue emission under 2540 Å, to incorporation of alkali atoms.

Phosphorescence and Thermoluminescence

A survey of the most important work of the past ten years was compiled by Stoeckmann and augmented by Przibram (36). It includes also *IR* stimulation. Of particular interest are: (*a*) the relations of doubly activated phosphors to photoelectric-conductivity and photography; (*b*) the application of reaction kinetics to electron exchanges in solid bodies; and (*c*) the investigations of traps and thermoluminescence.

Nelson and Berbert (37) and Bull and Garlick (38) recorded glow curves for Zn_2SiO_4:Mn:As. The arsenic serves only to produce exaggerated phosphorescence of the power law type. Their results are in essential agreement despite differences in composition and preparation of the phosphors. Bull and Garlick estimated that the number of traps introduced by arsenic was 50 times greater than in its absence and occurred when the manganese concentration was 100 times the arsenic. They measured the pronounced effect of arsenic in zinc beryllium silicate, zinc cadmium silicate, and cadmium silicate but found no effect in the silicates of calcium, strontium, barium, and magnesium activated with manganese.

Wallick (39) measured the thermoluminescence of 92ZnS·8CdS:Cu and ZnS:Ag and found that segregated crystals 14 microns in size respond the same as the original mixture from −160° to 0°C, whereas smaller crystals contain more shallow traps. There was no effect of size on phosphorescence. Hull and Mason (40) studied the electron trap distribution in the *IR* sensitive phosphors of zinc sulfide activated with Cu:Mn, Cu:Pb, and Mn:Pb, and conclude that long wave length radiation discloses classes of traps for which no evidence is given in glow curves. In an extended discussion of electron traps, Wise (41) considers their possible relation to the F and F′ color centers of alkali halides. Schoen (42) discussed the electron transitions in sulfides at different temperatures and the evaluation of glow curves, with many references to papers dealing with the subject.

Related to the *IR* sensitive sulfides are the calcium oxide phosphors of Janin, Crozet, and Clerc (43), activated with combinations of copper, lead, and manganese. Neither copper nor manganese alone showed *IR* sensitivity. Strong sensitivity was shown by combinations of manganese with copper or lead, especially the latter, in the range of 0.9–1.6 microns.

The stimulation and quenching of stored luminescence by ultrasonic radiation have been demonstrated by Schreiber and Degner, and by Eckardt and Lindig (44) for sulfide phosphors. The strongest effects appear to have been shown by ZnS:Cu and SrS:Bi.

Theoretical Interpretations

Williams (45) evaluated quantitatively the absorption and emission spectra of KCl:Tl for various temperatures and calculated the electron transitions responsible for them. The dependence of spectral emission and intensity upon temperature and exciting wave length were correlated with the absorption data on this phosphor by Johnson and Williams (46) for the purpose of providing a detailed picture of the energy relationships. The energy levels obtained for two excitation states account for the occurrence of a three-band emission. A fourth band appears on the introduction of cadmium and its position is also accounted for. Klick (47) utilized an alternate procedure for arriving at these relationships. His results are in agreement with Williams for the same phosphor. They indicate that his method may be used for other simple phosphors to calculate configurational coordinates from experimental data. This method has been applied by Klick and Schulman (48) to determine the potential energy curves of the levels involved in optical transitions of divalent manganese ions in zinc silicate. These curves are in agreement with excitation and emission bands and with their optical characteristics. The curve for the first excited state is displaced so slightly, 0.06 Å, from that of the ground state as to indicate that therein lies the cause for the effectiveness of manganese in so many phosphors and also for the reported asymmetry of its low temperature emission.

Schoen (49) showed that the calculation of similar characteristics for sulfides must be corrected for changes in lattice orientation that result on excitation. He proposed also an energy diagram to account for the radiationless transitions and discussed his conception of losses in excitation energy to the lattice.

In samarium-activated tungstates and molybdates, the decrease in the bluish emission of the basic compound on increase in temperature is accompanied by an increase in the red samarium emission. To account for this, Botden (50) developed a theory of resonance transfer of excitation energy that may extend over many lattice sites. He extended the theory to account for the occurrence of sensitized luminescence which results from the transfer of the excitation energy of the sensitizer ions to activator ions. The latter are incapable of responding directly to photoexcitation. He based his conclusions on measurements for the change in quantum efficiency with temperature for the phosphors $Ca_3(PO_4)_2$:Ce:Mn and $Sr_3(PO_4)_2$:Sn:Mn. He considered other cases also, such as the halophosphates.

Leverenz and North (51) presented evidence that luminescence centers formed by manganese ions in zinc silicate interact over several interatomic spacings. Arpiarian and Curie (52) described two systems of electronic levels to account for the distinct behavior of iron and nickel, as compared with cobalt, in quenching luminescence. Pfeiffer and Fonda (53) ascribed the abnormal emission of the yellow fluorescing zinc silicate to distortions in structure extending over several unit cells.

The theories for the origin of multiple band emission in phosphors activated with divalent manganese have been reviewed and discussed by Kroeger and Zalm (54), on the basis of all accumulated evidence. Of the two theories already proposed, Weyl's coordination theory and Maurer's cluster theory, the latter is preferred because its insufficiencies seem less important than those in the coordination theory. Schulman (55) disagreed and discussed grounds for the existence of serious errors in the four assumptions made by Kroeger to support the cluster theory.

Electroluminescence

D-c electroluminescence in silicon carbide, germanium, and silicon were studied by Lehovec and coworkers and by Haynes and Briggs (56). They attribute it to optical recombinations of electrons and holes at N-P junctions. The electroluminescence of single crystals of copper-activated zinc sulfide has been studied by Piper and Williams (57). The light increased exponentially with applied d-c voltage. With AC, the average light output varied linearly with the frequency. Below a critical voltage only light appeared which was out of phase with the voltage. Above this value, additional light appeared which was in phase with the voltage and increased rapidly with the voltage. Similar work has been reported by Böer and Kuemmel (58).

Roberts (59) made comparative tests on a copper-activated zinc sulfoselenide powder suspension in a variety of dielectric matrices. The only effect of the dielectric is apparently to modify the electric field in the phosphor. The brightness depends critically upon the field thus produced. Increasing the dielectric constant of the matrix augments the electric field in the phosphor, thereby enhancing the brightness. The brightness does not depend critically upon the temperature in the range −100° to 50°C.

Radioluminescence

Morrish and Decker (60) determined the phosphorescence decay of pure potassium chloride emitting at 4550 Å and 5300 Å, and of lithium fluoride emitting in the UV after irradiating with x-rays at various temperatures. The initial decay was ascribed to F′ centers and the final, to F centers. Sodium chloride activated with 1 per cent AgCl has been found by Furst and Kallman (61) to be as efficient under gamma radiation as anthracine. There is no luminescence under UV or visible light until it has been exposed to high energy radiation. Excitation by gamma rays is presumed to liberate electrons which are trapped at the lattice vacancies of color centers. Stimulation by light elevates them to the conductivity band and further transitions give rise to phosphorescence. Jentschke and coworkers (62) measured the

fluorescence efficiencies of sodium iodide activated with thallium under excitation by electrons and heavy particles and found it to be stronger than anthracine.

Schulman and coworkers (63) reviewed the subject of radiophotoluminescence and concluded that silver-activated glass furnishes the most satisfactory means for measuring doses of gamma rays from ten to a few thousand roentgens. Their dosimeter is reasonably independent of energy, it is stable with time, and is not seriously affected by exposure of the glass to UV or to temperatures from −70° to 100°C.

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Current Affairs

Electrochemical Society Condemns Astin Dismissal

When Secretary of Commerce Sinclair Weeks announced last March that he had asked for the resignation of Dr. Allen V. Astin, Director of the National Bureau of Standards, he brought down upon himself a storm of protest. The only specific reason given by the Secretary for his action was that in his opinion the Bureau had not been "objective" in its testing of a commercial mixture claimed to increase the life of lead-acid batteries.

The Board of Directors of The Electrochemical Society, meeting in New York on April 12, voted unanimously to make a formal protest, which was sent to President Eisenhower, Secretary Weeks, and the Small Business and Commerce Committees of the Senate. The statement was given to the press by Dr. J. C. Warner, President of the Society, on April 14 and to the members of the Society in the course of his Presidential Address. The text of the statement was as follows:

Text of Protest

"The Electrochemical Society strongly condemns the dismissal of Director Astin of the National Bureau of Standards prior to a full and impartial investigation of charges which question the integrity of the Bureau. This arbitrary action of the Secretary of Commerce, casting doubt as it does upon the integrity and competence of government scientists and government laboratories, will seriously impair the operation of the Federal Trade Commission, the Food and Drug Administration, and other federal agencies established for the protection of the public. The Society takes a grave view of the challenge which this action implies to the promulgation of standards by government laboratories. The Society is alarmed about the devastating effect of the summary dismissal of Dr. Astin upon the morale of technical personnel in the government service and on the ability to recruit in the future such personnel. This unfortunate action is particularly lamentable in this period of international tension when the welfare of our citizens leans so heavily upon our ability to maintain superiority in science and technology.

"The Electrochemical Society urges that Congress authorize a thorough investigation of the scientific facts in the case and invite the leading technical societies to nominate a group of qualified scientists and engineers to undertake this task and make public its findings.

"Finally, the Society believes that nothing short of restoring Dr. Astin to his former position can begin to repair the damage and injustice done the National Bureau of Standards, its director, and technical employees."

Weeks Reverses Stand

This and similar protests from technical societies and many individuals apparently helped persuade Secretary Weeks to reverse his position. On April 17, Mr. Weeks announced that he had asked Dr. Astin to remain as Director through the summer. A new committee, to be appointed by the National Academy of Sciences, is to appraise the quality of the Bureau's work on battery additives, and to make a definitive statement on the merits of the one in question. This belated acceptance by Mr. Weeks of the suggestion made by Dr. Astin on March 4 is in accord with the proposal of The Electrochemical Society as quoted above.

Two other groups of technical men are to advise Secretary Weeks concerning the Bureau. A special committee composed of members from seven scientific and engineering societies and headed by Dr. M. J. Kelly, president of Bell Telephone Laboratories, will evaluate the functions and operations of the Bureau as a guide to future policy. The National Bureau of Standards Visiting Committee, of which Dr. R. F. Mehl, Director of the Metals Research Laboratory of the Carnegie Institute of Technology, is chairman, has been asked to submit a panel of names from which Mr. Weeks can expect to select a successor to Dr. Astin.

5th Meeting of CITCE in Stockholm in July

The fifth annual meeting of the International Committee of Electrochemical Thermodynamics and Kinetics (CITCE) will take place in Stockholm, Sweden, on July 25 to 28, 1953, i.e., immediately before the International Congress of Pure and Applied Chemistry.

The program of the meeting will include papers under the following headings:

1. Fundamentals: Electrochemical Nomenclature and Definitions.
2. Experimental Methods in Electrochemistry.
3. Electrochemical Behavior of Metals and Non-Metals: 3.1 Potential—*p*H Diagrams (Equilibrium Diagrams and Practical Diagrams); 3.2 Polarization Curves; 3.3 Miscellaneous.
4. Applications to Corrosion.
5. Electrolytic Phenomena.
6. Applications to General and Analytical Chemistry.
7. Miscellaneous.

Information concerning the organization of the meeting can be obtained from the Secretary General of the Committee (CITCE), Dr. Marcel Pourbaix, University of Brussels, Brussels, Belgium; from the Secretary for Sweden, Dr. Uno Trägårdh, Royal Institute of Technology, Stockholm, Sweden; or from the President of CITCE, Dr. Pierre Van Rysselberghe, University of Oregon, Eugene, Oregon.

High Registration, Varied Symposia Score Success at N. Y. Meeting

The largest registration in the history of the Society was recorded at the 103rd meeting in New York, on April 13–17. A total of 712 members and guests attended the technical sessions and social functions. Of this number, about 60 were women.

The technical program presented sessions sponsored by the Electric Insulation, Electronics, Electro-Organic, Electrothermic, and Theoretical Divisions and offered a total of 135 papers. The 3-day symposium on "Application of Electrochemistry to Biology and Medicine" drew a large and interested audience, and the Electronics sessions, including Round Tables on Luminescence and Phosphor Screen Application, also were well attended. Keen interest and a good attendance likewise characterized the sessions of the other Divisions participating. The sizable group present at the Richards Memorial Lecture on "Transistor Physics," by Dr. William Shockley, indicated the interest in this particular field.

Heading the social calendar, was the Reception for Dr. and Mrs. Warner on Tuesday evening, followed by the Annual Banquet. In his presidential address, Dr. Warner expressed the Society's appreciation to all of the committee chairmen and others who had contributed to the splendid success of the meeting.

President Warner also suggested an expression of appreciation to Dr. Colin G. Fink, Honorary Chairman of the New York Meeting, for his distinguished service to the Society over a period of many years. A resolution was offered to this effect, and seconded, by members on the floor.

Another feature of the banquet was the annual awards of the Young Author's Prize and the Francis Mills Turner Memorial Award.

Young Author's Prize

The Young Author's Prize of $100 and a year's membership in the Society was presented to W. E. Kuhn of The Carborundum Company, Niagara Falls, New York (see group picture), for his two papers, "Production of Titanium Ingots by Melting Sponge Metal in Small Inert Atmosphere Furnaces" and "Development of Graphite Electrodes and Study of Heat Losses with Different Electrodes in the Single Electrode Inert Atmosphere Arc Furnace"; both of these appeared in the March 1952 issue of the JOURNAL.

Mr. Kuhn was born and educated in Toronto, Ontario, and graduated with honors in metallurgical engineering from the University of Toronto in 1934. He then joined the Ontario Research Foundation and, in December 1944, was appointed Research Fellow to work on a fellowship sponsored by Turbo Research Limited, and later by the National Research Council, Ottawa. This work was concerned with an investigation of properties of titanium made from powder, for possible use in gas turbines for jet aircraft. A paper covering certain phases of this work was published by Mr. Kuhn and two other authors, for which they were awarded the Leonard Medal in 1951 by the Engineering Institute of Canada.

Following three years with the Titanium Alloy Manufacturing Division of National Lead Company, Niagara Falls, Mr. Kuhn joined The Carborundum Company in 1952 as research engineer, to supervise research on zirconium and related metals.

Top row, left. Seen at the reception preceding the informal dinner on Monday evening are R. S. McKay, the Society's new President; Max A. Lauffer, of the University of Pittsburgh, speaker at the dinner; O. H. Bauer; Henry B. Linford; and Harry R. Copson, General Chairman for the New York Meeting. *Center:* Recent Past Presidents of the Society who attended the meeting—George W. Heise, R. M. Burns, W. C. Moore, R. M. Hunter, not-quite-Past President J. C. Warner, and C. L. Faust; seated are Mrs. Burns, Mrs. Moore, Mrs. Hunter, and Mrs. Warner. *Right:* Leading figures in the "Biology and Medicine Symposium" talking it over with Editorial Director R. M. Burns (*right*) at the reception Monday evening are (*left to right*) H. H. Jasper, L. R. Blinks, George Scatchard, and T. Shedlovsky.

Bottom row, left. John R. Musgrave and W. C. Lilliendahl relaxing during the Luminescence Section's social hour Monday afternoon. *Center, left:* A group at the reception preceding Monday night's dinner—Clifford A. Hampel, Mrs. A. S. White, O. W. Storey, and Mrs. E. F. Kiefer. *Center, right:* J. C. Warner, Society President, awarding the Young Author's Prize to W. E. Kuhn at the banquet Tuesday evening. *Right:* Incoming and outgoing "First Ladies," Mrs. R. J. McKay (*left*) and Mrs. J. C. Warner.

Left: John R. Dunning, Dean of Engineering at Columbia University, addressing the Society luncheon on Monday. Also visible in the picture are R. J. McKay, Marvin J. Udy, H. H. Uhlig, and Hans Thurnauer, newly elected 3rd Vice-President. *Center:* Group of ladies about to start the gay whirl of "ladies' activities" arranged for Tuesday by Mrs. A. C. Loonam, Chairman of the Ladies' Committee for the meeting. *Right:* William Shockley, of Bell Telephone Laboratories, delivering the Richards Memorial Lecture on Wednesday afternoon.

Turner Memorial Award

P. T. Gilbert of The British Non-Ferrous Metals Research Association, London, was the winner of the Francis Mills Turner Memorial Award, Sponsored by the Reinhold Publishing Company, consisting of $100 worth of books

P. T. GILBERT

and a year's Electrochemical Society membership. His paper, entitled "The Nature of Zinc Corrosion Products," appeared in the January 1952 issue of the JOURNAL.

Dr. Gilbert studied at the University College of the Southwest of England, Exeter, and was awarded the B.Sc. degree in chemistry by London University in 1943. He then joined the Corrosion Section of British Non-Ferrous Metals and carried out research on the corrosion of zinc and galvanized steel in supply waters. He received the Ph.D. degree from London University in 1950 for a thesis based on this work, and for work included in the prize-winning paper mentioned above.

He was appointed head of the Corrosion Section of the B.N.F.M.R.A. in 1948. He has published a number of other papers, mainly on various phases of work in the corrosion field.

Candidates Nominated for Society Offices, 1954

The Nominating Committee, appointed at the April 12 Board of Directors' meeting in New York, reported at an adjourned session on April 14 that the following candidates were proferred for offices in the National Society for the coming year:

For President—

Marvin J. Udy

For Third Vice-President—

Norman Hackerman
Fred W. Lowenheim
John R. Musgrave

The two other Vice-Presidents, H. H. Uhlig and Hans Thurnauer, since they were elected for a three-year term, will automatically become first and second Vice-President, respectively.

The above slate will be voted on in the fall ballot-by-mail election—the successful candidates to assume office in the spring of 1954. This report was submitted by H. R. Copson, John F. Gall, R. M. Hunter, H. J. Read, and G. W. Heise, Chairman.

Peter Debye Honored

Professor Peter J. W. Debye, Nobel Laureate and professor of chemistry, Cornell University, was honored at a formal luncheon on April 15, 1953 under the auspices of the Electric Insulation Division. Professor T. G. Bullen, Iona College, delivered the Invocation.

A scroll bearing the following inscription was presented to the guest of honor:

"The Electric Insulation Division of The Electrochemical Society acknowledges its indebtedness to P. Debye without whose imagination, vision, and inspiration many advances in dielectrics would not have been possible."

In his talk entitled "An Historical Interpretation of the Concept of Molecular Charge," Dr. Debye reviewed the

Peter J. Debye speaking at the luncheon meeting of the Electric Insulation Division on Wednesday. On the right is J. R. Bukey, Division member.

provocative suggestions of Van der Waals and Condon on molecular attraction, emphasized the magnitudes of intermolecular forces predicted from their equations, and told of recent significant experimental work at Utrecht establishing the value of x in the reduced equation of state $\left(\alpha + \frac{3}{\beta x}\right)(3\beta - 1) = 8\gamma$ as 2.3 – 3.3.

ASTM Annual Meeting

The 1953 annual meeting of the American Society for Testing Materials will be held in Atlantic City from June 29 through July 3. Program will appear in the May ASTM Bulletin.

Industrial Progress in Canada—1952*

A. C. Holm

Releases from the Dominion Bureau of Statistics covering the calendar year 1952 confirm earlier observations that Canada last year reached a new peak in its postwar prosperity, surpassing the previous record-breaking year, 1951, by a comfortable margin on almost all counts. The following are increases in 1952 as compared to 1951:

Gross National Product—	up 6%
National Income—	up 6%
Wages, Salaries, Miscellaneous Income—	up 12%
Public and Private Capital Expenditure—	up 12%

For the seventh consecutive year Canada's budget has produced a surplus, despite large expenditures on defense and steady reduction of the national debt; since 1946 the per capita debt has fallen about 31%. This happy state of affairs has brought about a long-awaited reduction of personal income taxes (about 11%) and of corporation taxes (6 – 10%), both to take effect in July 1953.

All major props of Canada's economy—agriculture, forestry, hydroelectric power, manufacturing, and mining—contributed to this peak prosperity. Canada's farmers garnered a record wheat crop. The pulp and paper mills achieved an output second only to their all-time record high of 1951; newsprint exports, dollar-wise the country's largest export commodity, surpassed 1951 levels by about 3%. Production of electric energy in Canada reached 61,786 million kilowatt hours, up 8% over 1951. The volume index of industrial production reached a peak of 248.0% in October 1952 (1935–1939 = 100), all but three months recording increases over the 1951 average of 226.5. Value of Canada's mineral output touched a new high of $1,278,000,000, up 4.1% over 1951.

Exports reached a new peak of $4,714 million, up 16% over 1951. In contrast to the two preceding years, international trade yielded a net surplus, estimated at about $250 million. As in previous years, the United States and Canada remained "best customers," each country doing more export and import business with the other than with any other country. Some 54% of Canada's exports went to the U. S. in 1952, and about 74% of its imports originated there.

This report on the interesting industrial situation in Canada—with particular attention to the extensive electrochemical and metallurgical advances—was prepared by A. C. Holm, Regional Editor of the JOURNAL for Canada.

New Projects for 1953

All signs point to a continued high level of prosperity through 1953. Investment in new plants and exploration and exploitation of new mineral deposits is proceeding at a brisk pace. The most spectacular projects now underway are the development of the huge Ungava (Quebec) iron ore deposits, the drilling for oil and natural gas in Western Canada, and the creation of a new aluminum smelter and hydroelectric plant in British Columbia. But an unprecedented number of other new enterprises have been started or planned throughout the length and depth of Canada, based on petroleum, natural gas, refinery and smelter gases, forest products, hydroelectric power, salt, pyrites, asbestos, and ores of copper, lead, zinc, nickel, cobalt, iron, tungsten, titanium, and uranium.

The following projects of an electrochemical or electrometallurgical nature underway or announced in 1952 will be of special interest to readers of the JOURNAL:

Chlorine and Caustic Soda

BRITISH COLUMBIA—New company, Hooker Chemicals Ltd., Vancouver, formed by the Hooker Electrochemical Company to produce chlorine for pulp bleaching.

ALBERTA—A $3 million plant is scheduled for Duvernay by Western Chemicals Ltd., Calgary.

ONTARIO—The Dow Chemical Company of Canada will spend $2 million on expanded chlorine facilities at Sarnia.

Marathon Paper Mills is completing a new $3 million plant at Marathon for pulp bleaching.

QUEBEC—Dominion Tar and Chemicals completed a $1 million addition to its plant at Beauharnois.

Aluminum

BRITISH COLUMBIA—The Aluminum Company of Canada has started on what could become the largest aluminum producing center in the world at Kitimat, with an ultimate capacity of over 500,000 tons per year. Together with the necessary power developments this project will cost some $500,000,000. The immediate goal is 90,000 tons of aluminum in 1954.

QUEBEC—A 45,000-ton per year addition to the Isle Maligne smelter was completed in 1952.

Magnesium

QUEBEC—Completion of a fourfold expansion of electrolytic magnesium production is scheduled for 1953 by the Aluminum Company of Canada at Arvida; the capacity is thereby raised to 4000 tons a year.

Phosphorus

QUEBEC—The Electric Reduction Company of Canada will complete in 1953 a $5 million plant with two 18,000 KVA furnaces for elemental phosphorus at Varennes, thereby nearly tripling its productive capacity.

Ferrosilicon

QUEBEC—Electro Reagents (Quebec) Ltd., a wholly owned subsidiary of Dominion Magnesium Ltd., will complete in 1953 a new plant ($1 million) at Beauharnois to produce 6000 tons annually of 75% ferrosilicon for use in magnesium production.

Calcium Carbide

ONTARIO—North American Cyanamid Ltd., at Niagara Falls, completed in 1952 a new carbide furnace and expansion of calcium cyanamide facilities at a cost of about $4.5 million.

Tungsten

BRITISH COLUMBIA—Kennametal of Canada Ltd. has begun the production of tungsten carbide directly from tungsten ore at its new refinery at Port Coquitlam, B. C.

Titanium Slag

QUEBEC—The Quebec Iron and Titanium Corporation at Sorel is bringing, during 1952–1953, its remaining four electric smelting furnaces into production. The five installed furnaces are designed to treat 1500 tons of Quebec ilmenite ore daily, producing some 700 tons of 70% titanium oxide slag and 500 tons of medium carbon steel daily.

Dry Batteries

ONTARIO—National Carbon Ltd., Toronto, expects to complete a $1 million dry battery plant at Walkerton in 1953.

Unconfirmed press reports suggest that serious consideration is presently being given to the possibility of establishing an electric zinc smelter and an additional calcium carbide plant in the Province of Quebec and a huge electrometallurgical enterprise in the Yukon.

Production of Electric Energy

Keeping pace with Canada's burgeoning industries, the installation of new hydraulic turbine capacity reached a record high in 1952 of about 1 million horsepower, bringing Canada's total developed water power to 14,304,000 hp. During 1953 another 950,000 hp is scheduled to be completed, and during 1954-1956 firm plans have been announced to bring in another 2.4 million hp. In addition some 690,000 kw of thermal power is being installed during 1952-1953, with another 100,000 kw on order for completion by 1956. Thus, during the five years 1952–1956, Canada will have added over 5 million hp to her power-generating capacity, according to present published figures. In some quarters it is felt that this new supply will be insufficient to meet the demand and that still further additions will be required.

It is interesting to note that Canada produces yearly about 4220 kwhr per capita, over 96% hydroelectric. For comparison, the United States in 1950 produced only 2560 kwhr per capita, about 26% hydro energy. These figures illustrate the important role played by electric energy, and particularly low cost hydro power, in Canada's processing and manufacturing industries.

Despite her abundant supplies and untapped resources of hydro power, Canada exports to the power-hungry United States only about 4% of her output. One reason for this apparent parsimony is that hydrolectric resources adjacent to the U. S. border are generally in the areas of Canada's heaviest concentration of population and greatest domestic demand for power. But another reason is Canada's firm belief that she will need all her electric power to supply her own needs in the future for the refining and processing of indigenous raw materials.

That Canada is not being overcautious in this policy is to some extent confirmed by the report of the "President's Materials Policy Commission," which in June 1952 reported to the President of the United States that the U. S. would require by 1975 an output of electrical energy equivalent to about 7250 kwhr per capita per year. That this estimate may not be too far off the mark is indicated by the fact that the Province of Quebec, Canada's largest hydroelectric producer, is already consuming some 5600 kwhr per capita per year, compared to 3200 in 1939. Canada's policy in this matter was recently reaffirmed by her Minister of Resources, Honorable Robert Winters, in definitely rejecting a request by the Aluminum Company of America for use of the headwaters of the Yukon River to generate power for a proposed 200,000 ton per year aluminum smelter near Skagway, Alaska.

Fall Meeting Papers

Manuscripts in triplicate or abstracts (not to exceed 75 words in length) of papers to be presented at the Wrightsville Beach Meeting, September 13 to 16, must be received at Society headquarters, 235 West 102nd Street, New York 25, N. Y., *not later than July 1, 1953.*

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Fall Meeting at Wrightsville Beach, N. C., Sept. 13–16

The Electrochemical Society will hold its 104th meeting at Wrightsville Beach, North Carolina, on September 13–16. This is the location of the Harbor Island Testing Station and the Kure Beach Project of the International Nickel Company. It is about ten miles from Wilmington, N. C.

The Ocean Terrace Hotel will be convention headquarters.

In addition to The Electrochemical Society meeting at Wrightsville Beach, the annual meeting of the Sea Horse Institute is scheduled for September 16–18 and, also, the annual meeting of the Marine Borer Conference during the latter part of the week.

Sessions will be held on Corrosion and Electrodeposition; the Electrothermic Division have tentative plans for arranging a Round-Table Discussion; and the Battery Division is planning two Round-Table Discussions but no formal presentation of papers. Corrosion sessions will be held on Wednesday, September 16, which will coincide with the first day of the meeting of the Sea Horse Institute, and will be attended by members of both societies.

Tours will be arranged for the inspection of some of the interesting corrosion projects that are being carried out here.

Frank L. LaQue, who is head of the Corrosion Engineering Section, International Nickel Company, and also has charge of the Harbor Island-Kure Beach operations, is General Chairman of the fall meeting. Fred W. Lowenheim, Metal & Thermit Corporation, is Financial Committee Chairman. Since there is no local section of the Society at Wrightsville Beach, details of the arrangements have been assigned to staff members of the Nickel Company's testing station.

Division Activities at the Spring Meeting

Electric Insulation Division

As a result of the recent election, held by the Electric Insulation Division at its meeting on April 15 in New York, the following members have assumed the offices noted below:

Chairman—R. A. Ruscetta, General Electric Company, Schenectady, New York

Vice-Chairman—A. Gunzenhauser, Transisola, Inc., New York, N. Y.

Secretary-Treasurer—L. L. Deer, U. S. Naval Ordnance Plant, Indianapolis, Indiana

THOMAS D. CALLINAN, *Chairman* (1952)

Electronics Division

The luncheon and business meeting of the Electronics Division, held during the New York meeting, took place on April 14.

After calling the meeting to order, Chairman J. R. Musgrave read the report on Division activities during the past year. The Secretary read the financial report and informed the meeting that this year's Enlarged Abstracts booklet had proved so popular that the entire issue of 300 copies was sold out by noon on April 15th.

Symposia planned for the 1954 spring meeting include Luminescence, Rare Metals, Screen Application, Instrumentation, and Semiconductors.

A motion was made and seconded that the proposed changes to the Division's bylaws as published in the March and April issues of the Journal be approved. The reasons for these changes were discussed and a vote being taken, the motion was carried.

Dr. Froelich, Chairman of the Nominating Committee, submitted the following nominees for the 1953–1954 year:

Chairman—R. H. Cherry
Vice-Chairman (*Luminescence*)—J. H. Schulman
Vice-Chairman (*Rare Metals*)—A. U. Seybolt
Vice-Chairman (*General Electronics*)—A. E. Hardy

The term of *Secretary-Treasurer* (C. W. Jerome) has two more years to run.

There were no further nominations. The Secretary was instructed to cast a ballot for the above slate and, after the election, the new officers were introduced and responded.

C. W. JEROME, *Secretary-Treasurer*

Electro-Organic Division

Twenty-three members of the Electro-Organic Division attended the Divisional luncheon and business meeting at New York on April 15th.

Chairman C. L. Wilson presided at the brief business meeting and introduced Mr. Jack Bain, Advertising Manager of the JOURNAL, to the members of the Division. Dr. Sherlock Swann gave a brief discussion of the status of the literature in the electro organic field.

STANLEY WAWZONEK, *Secretary-Treasurer*

Electrodeposition Division

For the fall meeting of the Society the Electrodeposition Division is now arranging several sessions dealing with general problems of electrodeposition. Papers for this program are invited.

Triplicate copies of manuscripts or abstracts (not over 75 words in length) must be received at Society headquarters, 235 West 102nd Street, New York 25, N. Y., *not later than July 1, 195*

M. L. HOLT, *Chairman*

SECTION NEWS

Cleveland Section

"Electrical Properties and Constitution of Salt Melts" was the technical subject discussed at the Cleveland Section's meeting on April 7, with Frank E. W. Wetmore as the guest speaker.

Dr. Wetmore pointed out that very little is known of the constitution of concentrated electrolytes, especially molten salts. The method of study he used was that of transference and conductance in uniary and binary salt melts. He pointed out that there is no good explanation of what happens in such concentrated systems.

The after-dinner speaker at the meeting was Dr. John L. Sloop, chief of the Rocket Branch of the Lewis Flight Propulsion Laboratory. Dr. Sloop explained and showed models of rocket engines for aircraft and for rocket

* * *

On April 12 the Cleveland Section sponsored a TV show on "Primary Batteries" over station WNBK as part of the Cleveland Technical Societies project. R. W. Erwin, National Carbon Company, is the Section's chairman of this committee. Dr. R. S. Johnson and Dr. C. L. Hildreth, both of National Carbon Company, took part in the broadcast.

New York Metropolitan Section

At the April 1st meeting of the New York Metropolitan Section an enthusiastic audience heard a discussion of molybdenum by two speakers from the Westinghouse Electric Corporation.

W. C. Lilliendahl of the Research Department, Lamp Division, at Bloomfield, N. J., discussed the occurrence, preparation, production, and industrial importance of the metal.

The need for new metals or alloys that will withstand unusual stress at relatively high temperatures has become of paramount importance in heat engines of the present and future, he said. Materials with high melting points, good hot-creep resistance and strength, cold ductility, and some degree of impact strength are required. Molybdenum shows considerable promise in these applications.

The metal is produced by arc-casting or by powder metallurgy processes, although both make use of molybdenum powder as a starting material. Nonmetallic impurities have considerable effect on the properties of the metal. Metal as currently produced shows no ductility in the fully crystallized state except at very low strain rates, Mr. Lilliendahl said. However, very good ductility has been observed in the worked, stress-relieved or partially recrystallized state.

J. H. Bechtold of the Research Laboratories at East Pittsburgh described the physical, chemical, and mechanical properties of molybdenum.

Although the metal is quite resistant to most chemicals, he stated, it is readily attacked upon exposure to air at temperatures above approximately 300°C. Much emphasis is currently being placed on the improvement of the oxidation resistance of the metal by the application of coatings or by the formation of alloys.

The tensile properties of molybdenum fall into four ranges of temperature: a brittle zone up to −75°C, a transition zone from −75° to 100°C, a ductile zone from 100° to 900°C, and an unstable zone above 900°C. To improve mechanical properties, Mr. Bechtold said, it is desirable to shift simultaneously the unstable zone to a higher temperature, and the transition zone to a lower temperature. The unstable zone can be raised by solid solution alloying. The transition from ductile to brittle behavior is due to rapid increase in yield strength, or resistance to deformation, with decreasing testing temperature. The creep properties of molybdenum above about 900°C are determined by the recrystallization temperature.

An enjoyable dinner and social hour preceded the technical session.

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REH 7-30	1200 w.	24 v.	0.44 Ω	2-3/4"	7-7/8"
REH 7-60	1800 w.	46 v.	1.05 Ω	2-3/4"	19-3/4"
REH 10-30	1800 w.	34 v.	0.59 Ω	4"	7-7/8"
REH 10-60	2500 w.	63 v.	1.44 Ω	4"	19-3/4"

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Niagara Falls Section

The April 8 meeting was "Ladies' Night" for the Niagara Falls Section. Following the social activities, the guest speaker, James O'Malley of Bell Aircraft Corporation, spoke to the group on the subject "Modern Research Aircraft."

In addition to the above meeting, the Niagara Falls Section sponsored a two-hour panel discussion on the subject of "Non-Metallic Materials of Construction for Chemical Process Equipment" at an Industrial Conference held by the Technical Societies Council of the Niagara Frontier in Buffalo, New York, April 22. The Niagara Falls Section supplied a moderator and four speakers for this panel discussion.

Milton Janes, *Secretary-Treasurer*

Pacific Northwest Section

The spring meeting of the Pacific Northwest Section was held on Friday March 20 at Rose's Highway Inn, near Tacoma, Washington. Prior to the meeting a field trip was conducted through the chlorine and caustic soda manufacturing facilities of the Pennsylvania Salt Manufacturing Company of Washington.

The speaker for the evening was Professor W. Rylan Hill, of University of Washington, who discussed "Electronic Instrumentation in the Chemical Industry."

At the annual business meeting which was held after Professor Hill's talk, the following officers were elected to serve for the 1953–1954 term:

Chairman: Glen C. Ware, U. S. Bureau of Mines, Albany, Oregon

Vice-Chairman: Joseph B. Heitman, Pennsylvania Salt Manufacturing Company of Washington, Tacoma, Washington

Secretary-Treasurer: G. H. Kissin, Division of Metallurgical Research, Kaiser Aluminum and Chemical Corportion, Spokane, Washington

G. H. Kissin, *Secretary-Treasurer*

Washington-Baltimore Section

The Washington-Baltimore Section held its 18th technical meeting on March 19, 1953, at the National Bureau of Standards.

W. J. Schwerdtfeger of the Bureau of Standards spoke on "Potential Measurements in Cathodic Protection."

The speaker said that while the theory of cathodic protection is generally understood, present techniques for determining the amount of current

required for protection are based chiefly on potential measurements. The proper interpretation of a potential measurement, made while the protective current is flowing to a structure, requires a consideration of the geometrical factors associated with a corrosion circuit and also the resistivity of the corrosive medium.

Following a presentation of the theoretical considerations, Mr. Schwerdtfeger's remarks were centered on experimental laboratory data. Emphasis was placed on the proper positioning of the potential reference electrode by data obtained on bimetallic models corroding in a solution which caused relatively little polarization but brought out the effect of solution resistance. Data were also presented as obtained on similar models corroding in a solution which caused polarization to be predominant.

FIELDING OGBURN, *Secretary*

India Section

Symposium on Electrolytic Alkali-Chlorine

The India Section symposium on "Electrolytic Alkali-Chlorine" was held at the Indian Institute of Science, Bangalore, on February 26, 27, and 28, 1953. The papers presented were:

1. Handling and Processing Equipment from Impervious Carbon and Graphite for Electrolytic Chlorine Industry—S. K. Vohra and C. J. Dadachanji
2. Utilization of Chlorine in the Electrolytic Production of Metals—T. L. Rama Char
3. Properties and Uses of Chlorinated Rubber—P. A. Porecha
4. Satisfying the Demand for Chlorine—V. Aravamuthan
5. Properties and Uses of Calcium Chlorite—P. A. Porecha
6. Future of the Chlorine Treatment of Sulfide Ores—V. Aravamuthan
7. Some Aspects of the Economics of Alkali-Chlorine—N. B. Shivaraman
8. Utilization of Surplus Alkali-Chlorine in the Production of Carbon Tetrachloride at the Spot—V. Aravamuthan.

There was a good-sized gathering drawn from research laboratories, electrochemical and electrometallurgical industries, and Government establishments. The members of the Indian Institute of Metals were also invited. The discussions that followed the papers were extremely interesting and formed an important part of the proceedings. The program was rounded off with a dinner and visits to research institutions and factories in Mysore State.

Symposium on Metallurgy in Electroprocess Industries

A symposium on "Metallurgy in Electroprocess Industries" was held at the Indian Institute of Science, Bangalore, on February 27, 1953, under the joint auspices of the India Section and the Indian Institute of Metals. Papers read were:

1. Some Developments in the Electrolytic Production of Aluminum—R. Thyagarajan, R. S. Ramachandran, and K. K. Cherian
2. Electrolytic Production of High Purity Manganese Metal and Manganese Dioxide—T. Banerjee
3. Materials of Construction in the Chlorine-Alkali Industry—S. Ramaswamy, R. V. Ramani, and N. Subramanyan
4. Amalgam - Metallurgy: Present Trends and Future Possibilities—J. Balachandra.

The presence of members of both the institutions greatly contributed toward a lively discussion. The members of the India Section were invited for the technical meetings and social functions arranged by the Indian Institute of Metals for their annual meeting.

T. L. RAMA CHAR
Regional Editor for India

2nd Request for ABC Questionnaire!!

Society members and subscribers who have not as yet returned the first ABC questionnaire (mailed in March) have been sent a second request. Please supply the information regarding job categories, which is needed by the Audit Bureau of Circulations (ABC) for a classification of JOURNAL readers, relative to advertising. *It is very important that everyone return this questionnaire promptly.*

Send to The Electrochemical Society, Inc., 235 West 102nd Street, New York 25, N. Y.

PERSONALS

IVY M. PARKER of Plantation Pipe Line Company has moved from Bremen, Ga., to the company's offices in Atlanta.

CHARLES P. ROBERTS, JR., Westvaco Chemical Division, Food Machinery & Chemical Corporation, has transferred from the Pocatello, Idaho, office to the company's plant at South Charlestown, W. Va.

PETER J. LIBRIZZI, formerly senior chemist and supervisor of the coating laboratory at CRT Division of Allen B. DuMont Laboratories, Clifton, N. J., is now associated with the development laboratories of CBS-Hytron at the Newburyport, Mass., plant, as development engineer and chemist.

I. MILTON LE BARON, International Minerals and Chemicals Corporation, Chicago, Ill., has been named Director of Research Laboratories of the Company, located at Skogie, Ill.

RAYMOND F. LEDFORD has left Sunbeam Corporation, Chicago, to become Director of Sales and Research at Industrial Filter & Pump Manufacturing Company, also of Chicago.

ROBERT R. BANKS, formerly of Armour Research Foundation, Chicago, has joined the Air Reduction Company, Murray Hill, N. J.

R. E. ZIMMERMAN has retired as Consultant, United States Steel Corporation, Pittsburgh, and is now residing in Short Hills, N. J.

A. B. HOEFER is now connected with F. B. Stevens, Inc., Detroit, Mich. Mr. Hoefer was previously with Udylite Corporation, Long Island City, N. Y.

V. ARAVAMUTHAN has been appointed junior scientific officer, Central Electrochemical Research Institute, Karaikudi.

B. A. SHENOI has been appointed senior scientific assistant, Central Electrochemical Research Institute, Karaikudi.

JOHN D. MORRON, Development Manager, United States Rubber Company, has transferred from Detroit, Mich., to the company's plant at Fort Wayne, Ind.

NEW MEMBERS

In April 1953 the following were elected to membership in The Electrochemical Society:

Active Members

Robert R. Adams, Battelle Memorial Institut fur Deutschland, Rheingau-Allee, 25, Frankfurt/Main, Germany (Electrodeposition)

Irving Amron, Sylvania Electric Products Inc., 35-22 Linden Pl., Flushing, N. Y. (Electronics)

William W. Bradley, Bell Telephone Laboratories, Murray Hill, N. J. (Corrosion)

John F. Dittman, The Eagle-Picher Company, mailing add: 431 Park Ave., Joplin, Mo. (Battery)

Fred W. Duggan, National Carbon Company, mailing add: 1995 Hampton Rd., Rocky River, Ohio (Battery)

Philip J. Elving, Department of Chemistry, University of Michigan, Ann Arbor, Mich. (Electro-Organic and Theoretical Electrochemistry)

Roman Evdo, U. S. Radium Corporation, mailing add: 379 Parkview Dr., Scotch Plains, N. J. (Electronics)

Alfonso Gomez, Sonolux, mailing add: Apartado Nacional 440, Medellin, Colombia (Electrodeposition, Industrial Electrolytic, and Theoretical Electrochemistry)

Fred L. Granger, Jr., National Carbon Company, mailing add: 18120 Ponciana St., Cleveland, Ohio (Battery)

John B. Harrison, Delco Remy Division, General Motors Corporation, Muncie, Ind. (Battery)

Moses G. Jacobson, J. T. Ryan Memorial Laboratory, Mine Safety Appliances Company, 100 N. Braddock Ave., Pittsburgh, Pa. (Battery, Electronics, and Theoretical Electrochemistry)

George J. Kiedaisch, Midwest Carbide Corporation, Box 554, Keokuk, Iowa (Electrothermic)

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Editorial

Consumer Contribution to Chemical Industry

THE intelligent consumer is making increasingly important contributions to the growth and progress of the chemical industry. As his needs have become more complex and his requirements more specific, the consumer has found that he can no longer, and that he should no longer, rely upon the manufacturer to anticipate his wants or solve his problems. Knowing best his own purposes, he has found that he must carry on research in his own interest, if he is to protect his future. The intelligent consumer must understand why compositions of matter behave as they do, if he is to feel assured of obtaining the fullest satisfaction of his needs in terms of quality of performance and cost. There should be nothing antipathetic in the user's ideal of perfect service and the producer's goal of reasonable profit; their interests are mutual. The results of consumer research benefit both the consumer himself and the chemical industry by developing new needs for chemical products and by extending the uses of chemical products through improvement of their quality. A few examples will illustrate this reaction of research of the user on the progress of the manufacturing industry.

Fundamental studies had indicated that silicon approaching intrinsic purity would have scientifically interesting and possibly useful electronic properties. This led a prospective user to persuade a chemical company to undertake a collaborative effort toward the development of a process for the commercial production of the highly pure product. With the success of this project, the user who sponsored and financed it got what he wanted—a source of super-purity silicon—and the chemical manufacturer got a new product he could sell profitably to the electronic industry.

A prospective large use of polyethylene was jeopardized by the discovery that some lots of the early production cracked when subjected to polyaxial stress. The problem was solved only by the research of the consumer which showed that the tendency to crack was related to the low molecular weight component of the polymer. The manufacturers were persuaded to modify their processes so as to shift the molecular weight range upward with the result that they now sell more than ten million pounds of polyethylene a year for an application that otherwise would now be using a product from outside of the chemical industry. Moreover certain other users of regular grade polyethylene have lately discovered that they too are having cracking troubles. Thus, it is evident that one element promoting the present prospective fourfold expansion of polyethylene production was consumer research.

Large containers molded from polystyrene had not been feasible owing to a tendency to crack. A study of the surface crazing of this material led a potential user of these moldings to propose temperature annealing for the elimination of the strains responsible for both crazing and cracking. The success of such heat treatment—a common practice in metallurgy—has led to large volume manufacture of large polystyrene moldings to the satisfaction of both consumer and producer.

It was the need of the user of organic finishes to control quality that led to his development of modern methods for the measurement of finish quality. In turn, the paint manufacturer was able to use these methods to gauge the improvement in finishes he has been able to make with the newer resins. The result has been a twofold increase in durability and service life in organic finishes!

The foregoing description of the impact of consumer research on the development of the chemical industry should suggest the importance of intimate research level contact between the two groups. The consumer should have the opportunity to guide the manufacturer toward the production of the new products that will best serve user needs. The highly competitive nature of chemical industry should not prevent confidential collaboration toward the achievement of mutually desirable goals. Spared the expense and manpower previously necessary for the solution of customer problems, chemical industry can devote more effort to research basic to future progress.

—RMB

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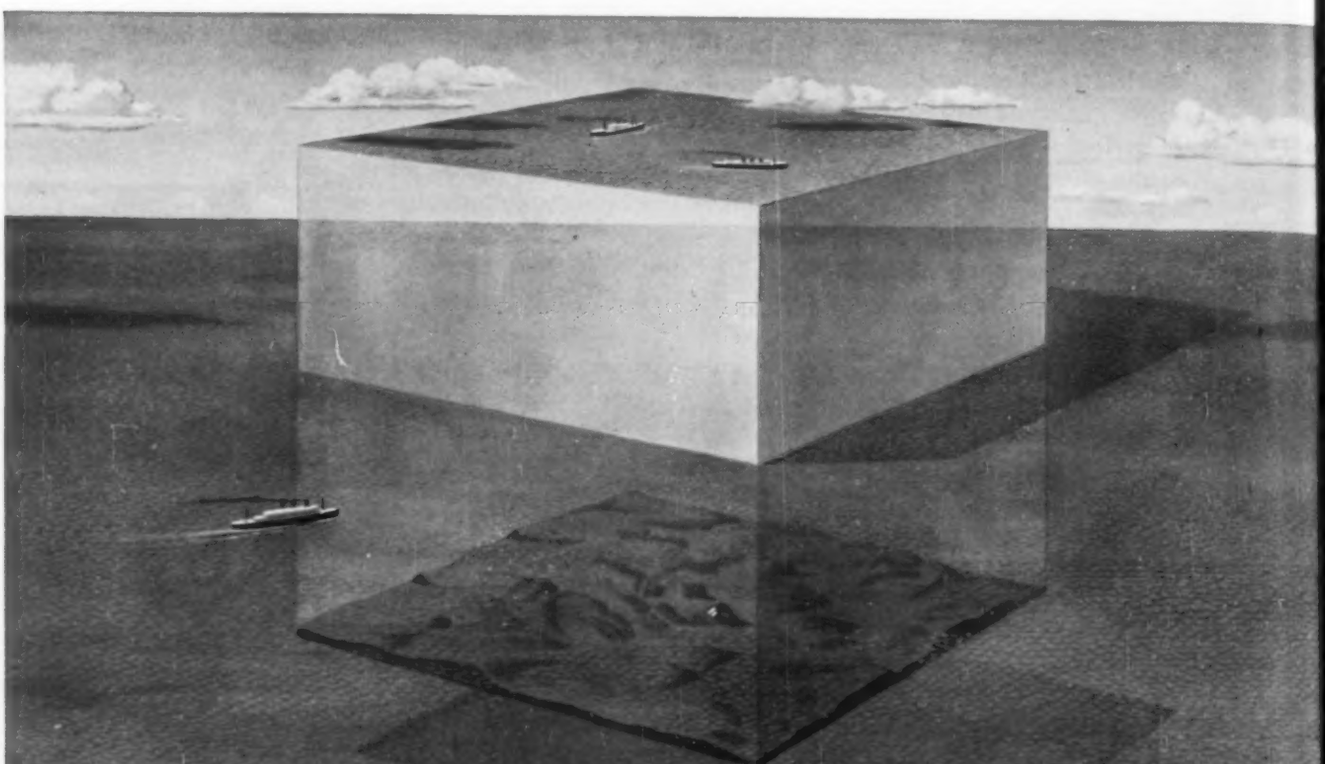

Today, when this nation is confronted with a crisis in our supply of many raw materials, it is of immense significance that the sea around us contains an almost unlimited supply of Magnesium. For Magnesium is light, strong, practical and versatile—the answer to many manufacturers' needs. Also, Magnesium is highly important in many electrochemical processes including cathodic protection.

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HE GOLDEN GULF COAST

General Introduction

Oliver Osborn[1]

he Gulf Coast today is moving through what may well he greatest industrial expansion of all times. Under the nuing impetus applied by the chemical industry, this on has become the setting for a mammoth demonstration merican ingenuity and creative ability. Little more than ecade ago, the coastal prairies of the Gulf were all but ty of industry. Those prairies have been transformed into strial sites on which, it has been estimated, three out of y four chemical plants built in the United States since 0 have been located.

What are these plants that, in little more than a decade, e come to represent an investment of some four billions dollars of capital? *Chemical Engineering*, in November, 1, stated that "at least 106 organic chemicals, 28 inorc chemicals, four elemental gases, five industrial fertilizer micals, plus carbon black, sulfur, aluminum, iron, tin, e, cadmium, salt, and other items are now produced by ustries in the Southwest." In the petrochemicals alone, re are now more than 50 producing plants on the Gulf ast vs. the three established prior to 1940.

Significant, although less phenomenal than the mark made the petrochemical field, has been the growth of the elecchemical industry along the Gulf Coast. In 1940, this se of chemical activity was virtually nil. Today, electroemical or electrothermic principles are being applied in the ic production patterns of a zinc plant, two magnesium nts, two sodium plants, four aluminum plants, eleven lorine-caustic plants, eight electric steel plants, and four ngsten powder plants.

This blossoming of the Gulf Coast was neither accidental r automatic. Industry has its reasons for choices of locaons for expansion. Something made the Gulf Coast truly olden" as an area for industrial activity, particularly for emical production. The factors are not difficult to perceive. Certainly an ever-increasing supply of oil and natural gas s been a major factor. Besides providing comparatively eap sources for fuel and power, these are also the basic raw materials for an almost infinite number of products. Moreover, increased consumption of these resources has been parallelled by new discoveries so that proven reserves remain more than adequate. And in addition to the nearly 100 trillion cubic feet of natural gas reserves now existing in Texas alone, the Gulf Coast has a host of other raw materials in a fabulous storehouse.

Natural resources of the Gulf Coast include such basic materials as sulfur, salt, lime, and seawater. Sulfur has been or is being mined at some two dozen different locations; known salt domes number close to 150. Lime is available as oyster shell in reefs and beds liberally dotting the miles of coastline. As for seawater, it is estimated that there are some 320 million cubic miles available and, furthermore, that a single cubic mile contains 100 times more magnesium than is necessary to satisfy the present annual national consumption.

The chemical industry looking at the Gulf Coast has also been attracted by the ready availability of large blocks of relatively cheap land. Selection of plant sites has been greatly simplified by the "wide open spaces." In addition, a mild climate has made possible the adoption of a new and cheaper construction pattern—that for "open air" plants. Finally, the Gulf Coast has been endowed with at least a dozen deep water seaports which, for added convenience and attractiveness, are cross-connected by the Intracoastal Canal extending from Brownsville, Texas, to Carrabelle, Florida.

Thus, when referring to this land of chemical bonanza, it is quite proper to speak of it not only as the Great Gulf Coast but also as the Golden Gulf Coast.

The papers which follow deal with processes of interest to the electrochemical industry. Based on Gulf Coast experiences, they describe some of the more important electrochemical industries and power generating methods of the region.

F. L. Kaestle, of the General Electric Company, covers the aluminum industry; W. J. Rave, of the Dow Chemical Company, Texas Division, tells of the sea water magnesium process; Frank Chrencik, of the Diamond Alkali Company, summarizes chlorine-caustic production; and H. L. Norris, Jr., of the Fish Engineering Corporation, describes some of the privately operated power plants of the area.

[1] Journal Regional Editor, Houston. The Dow Chemical ompany, Texas Division, Freeport, Texas.

THE ALUMINUM INDUSTRY OF THE GULF COAST AREA

F. L. Kaestle[1]

Foreword

Of all of the vast industrial expansion in the Gulf Coast area during and since World War II, no other major industry is comparable to the aluminum industry in the high percentage of total national production which has shifted to a new area in so short a time.

Considering basic reduction facilities alone, the Gulf Coast annual production capacity by the end of next year will be 920 million lb, or 31 per cent of the national total of 2900 million lb. And all of this has come to the area within the past four years.

Availability of low cost power or fuel is the primary factor in the location of aluminum reduction plants. For this reason, all earlier plants were located where abundant hydroelectro power was available. But not enough additional hydro power could be produced to support the additional aluminum production authorized in the past six years. It was natural that the industry should turn to the abundant fuels of the Gulf Coast for a large share of the recent expansion.

Until recently, natural gas alone has been the basic fuel for Gulf Coast industrial power. But with the advent of the new lignite-burning plant of the Aluminum Company at Rockdale, Texas, a second abundant source with a promising future has emerged.

Aluminum Production of the Area

When facilities now under construction are completed next year, the annual production of the four primary reduction plants of the Gulf Coast area will be approximately as follows:

Aluminum Company of America:	
Point Comfort, Texas	185 million lb
Rockdale, Texas	175 million lb
Reynolds Metals Company:	
Corpus Christi, Texas	160 million lb
Kaiser Aluminum Corporation:	
Chalmette, Louisiana	400 million lb
Total	920 million lb

In addition to the aluminum reduction plants, three of the nation's six large alumina plants located in the Gulf Coast area will process enough bauxite to supply alumina to all of the area's reduction plants and a substantial amount to reduction plants in other areas of the country.

The production of aluminum from the ore, bauxite, involves first, the processing of bauxite by the Bayer process to alumina, pure aluminum oxide; and then, the electrolytic reduction of alumina to the metal, aluminum.

Bauxite for United States aluminum production comes principally from Arkansas, Dutch Guiana, British Guiana, and more recently, from Jamaica. Other sources in Haiti and Brazil are being developed. Bauxite is usually found near the surface and mining is an open-pit operation. Arkansas ore is either processed nearby or shipped by rail to other alumina plants. However, by far the greatest amount of ore used in the United States comes by sea-going ore boats from the Guianas and Jamaica by way of the Caribbean Sea.

Hence, one of the most important factors in the economic location of an alumina plant for foreign ores is that it be on a harbor to the sea. The alumina plants of the Aluminum Company at Mobile, of Kaiser at Baton Rouge, and of Reynol at Corpus Christi emphasize this point.

It is the Gulf Coast's fortunate circumstance that econom power for aluminum reduction is also near these alumi plants.

The Alumina Process

In the Bayer-process alumina plant, bauxite, which h been finely crushed and washed, is treated with a solution hot caustic soda in which sodium-aluminate forms and go into the solution leaving the impurities in suspension. Af filtration, the solution is cooled in high-tower precipitati tanks. Under supercooled conditions, aluminum hydroxi crystallizes out of solution when "seeded" with like crysta from a former batch. The solid hydroxide is then washed fr of caustic and kiln-dried to produce aluminum oxide, alumina, in a fine white powder form ready for the reducti plant.

Under typical conditions, for each 100 lb of bauxite pro essed, approximately 40 lb of alumina is produced from whi 20 lb of aluminum will be reduced. In the process, 5 lb caustic are used and the equivalent of about 250 ft³ of g are required for heat for the kilns and for process steam Thirty kwhr of electrical energy are used to drive the grinder pumps, fans, conveyors, mixers, and other machines of th process.

Since the alumina process is a batch process and a reason able amount of alumina storage is feasible, the high degree continuity of service required in the reduction plants is n as essential for alumina plants. Over the past years, howeve the demand for increasing aluminum production has result in virtually around-the-clock capacity operation of all th major alumina plants. All of the Gulf Coast plants have al ready expanded since initial building or planning and all ar capable of further expansion when needed.

The Aluminum Reduction Process

In the aluminum reduction plant, alumina is reduced t aluminum in electrolytic furnaces which, in the trade, ar called "pots." A large number of pots are bus connected elec trically in series, to form a "potline." The voltage per pot i approximately five volts. A typical 750-volt line would hav about 160 pots of which 140 would be in service at one time

Each pot consists of a large rectangular, rather shallow iron shell, carbon lined, and having a movable carbon anod structure suspended in it. Alumina is dissolved in a bath o molten cryolite between electrodes. Direct current separate the aluminum oxide into aluminum which forms a molte layer on the bottom of the pot thereby forming the cathode and oxygen which, on contact with the hot anode carbon forms carbon dioxide which is drawn away by the ventilating fans.

Alumina is fed into the pot periodically at a rate of two pounds for each pound of aluminum produced. Molten alu minum is siphoned periodically into ladels, and thence trans ferred to holding furnaces from which it is cast into pigs for shipment. In the process, about one-half pound of anode car bon is consumed for each pound of aluminum produced.

For this reason, the anode carbon must be replaced con tinually. Two general types of pots are in common use having anode structures which make this carbon replacement feasible.

The first, and older in use, is the prebaked anode pot. In it the anode assembly has a movable steel structure with large

[1] Industrial Engineering Section, General Electric Company, Schenectady, New York.

node busbar headers, to which a large number of individual node studs are bolted. The individual anodes are precast around the stud assemblies and baked out in a separate carbon plant near the potroom. These anodes are replaced continually as needed. The replaced studs and their remaining carbon are reclaimed in the preparation of the next batch of anodes in the carbon plant.

The other type, the Sodeberg pot, has a movable structure which supports a single large rectangular carbon anode, contained by several rows of removable horizontal channels on both sides and ends. Electrical contact is made by iron slugs driven horizontally into the carbon through holes in each row of channels on the two sides. The anode flexibles connect these slugs to the anode assembly busbar headers.

As the anode is consumed and lowered, the lower channels are removed, the lower slugs are pulled, and both are replaced at a higher level. A finely ground carbon and pitch mixture is periodically added at the top of the anode. The carbon bakes out and graphitizes before reaching contact with the electrolyte. The Sodeberg pot must have its anode formed and baked out before starting initially, and the pot is more complex and expensive than the prebaked anode type, but the carbon plant operation is a simpler process.

Some of the Gulf Coast plants have one type of pot and some the other. Neither is being superseded by the other. The choice is one of over-all plant economy and of desirable operating characteristics as judged by the user for each plant.

Both pots use petroleum coke as a source of carbon, and refinery pitch as a mixer, since with these the desired purity can be controlled and obtained. These materials also are readily available from the refineries of the Gulf Coast.

Power Requirements for Aluminum Reduction

In the aluminum reduction process alone, the d-c energy required is from 8½ to 9½ kwhr/lb. As an easy estimating figure, this means that for each 100 million lb of annual capacity, there must be 100 thousand kw of d-c generating or a-c generating and conversion electric equipment, operated on a virtually 100 per cent load factor.

For the Gulf Coast's 900 million lb of aluminum, the 900 thousand-kw power plant represents an investment of $180 million if estimated at $200 per kilowatt, and if all gas fired, would consume over 200 million cubic feet of gas per day. This is the key to the basic aluminum industry. With little influence by other factors, it goes almost anywhere that the most economical electric power can be had or produced.

Lignite as a New Fuel Source

As the use of natural gas rose sharply, it was natural that other fuel sources of the area should be sought from which low cost power could be produced. Lignite now gives that promise. Extensive pilot plant work had been done by the Bureau of Mines, and that work has now been projected into a large scale power plant. To be operated by Texas Power and Light Company for Alcoa's new Rockdale reduction plant, it will give lignite its first job in the heavy industrial field. The operating results will be of great national interest.

In the processing of lignite for industrial use by the Parry process, a dry fuel, "char," which is analagous to coke from the coke oven, is produced along with relatively large quantities of coal tar. It is by reclamation of the valuable by-product tar, and its derivatives, that low net cost fuel is made possible.

Except for the adaptation of boilers to burn this specific fuel, char, the production of electric power is the same as that of any other modern coal-burning, steam-electric station of which the new Rockdale plant is a good example.

Alternate Power Systems from Natural Gas

Power production from gas-fired steam-electric stations is common utility practice on the Gulf Coast, and the Kaiser Aluminum plant at Chalmette, Louisiana, which will be the largest single aluminum plant of the area, produces 75 per cent of its power this way.

When natural gas is the fuel, the two common, and widely used power generating systems for large blocks of d-c power are: (*a*) steam-electric a-c generation with mercury arc rectifiers for conversion to d.c.; and (*b*) gas engines driving d-c generators, operating in parallel, and serving the potline directly.

Gas engines are used for all of the power at Alcoa's Point Comfort plant and Reynolds' Corpus Christi plant, and for 25 per cent of that at Kaiser's Chalmette plant. In approximate per cent of the total, the electric power for the Gulf Coast's aluminum reduction is produced as follows: 48 per cent by gas engines; 33 per cent by gas-fired boilers and steam turbines; 19 per cent by lignite-fired boilers and steam turbines.

There is no intent to make any economic comparison of the power systems themselves in this discussion. But each of the Gulf Coast's plants, the power systems it uses, and the plant's principal features are of interest.

Kaiser Aluminum and Chemical Company, Chalmette, Louisiana

The Kaiser Aluminum Company's reduction plant at Chalmette, Louisiana, near New Orleans, will have an annual capacity of 400 million lb for eight similar potlines, each of approximately 50,000-kw capacity.

Each of the first two potlines is served by a power plant having gas engines driving d-c generators. The other six potlines are served by mercury arc rectifiers, receiving power from Kaiser's new gas-fired steam-electric station.

Each of the two engine power plants contains 40 Nordberg vertical, radial, gas engines, each driving a 1290-kw, 750-volt G-E d-c generator. All generators are operated in parallel, each being connected to the potline bus by two circuit breakers.

The 250-volt shunt fields of all generators are served from a common station field bus, to which either of two alternate synchronous motor-driven main exciters may be switched. Each main exciter is controlled by an amplidyne exciter, used in this case as a high-gain amplifier, thereby permitting full voltage range control of the entire potline by means of a single low-power automatically controlled potentiometer for the amplidyne control field.

An engine-generator control cubicle mounted near its engine permits the floor operator to start each engine and parallel the generator on the potline bus. The master operator's panel provides load indication and control for each generator for proper division of load between units, and the over-all potline load control and metering equipment.

Since full range voltage control is available, each generator can be paralleled on the bus at no load, at the existing potline voltage at any time. Therefore, no main potline breaker is required.

All of the engines' auxiliaries (except the ignition system) such as, lube oil and water pumps, cooling fans, etc., are driven by standard 480-volt, 60-cycle induction motors, all served from a multiplicity of load center substations which, in turn, receive power at 13,800 volts from several alternate

feeders from the plant power services of the steam station.

Each engine is cranked by using its connected d-c generator as a starting motor. When the potline is at or near normal operating voltage, any individual unit is started from a station starting bus which is then fed through a resistor from the potline bus. For start-up on a "dead" potline, the starting bus then is served by one of the normal exciter generators. Each engine is then brought to firing speed by means of variable voltage control of this exciter generator.

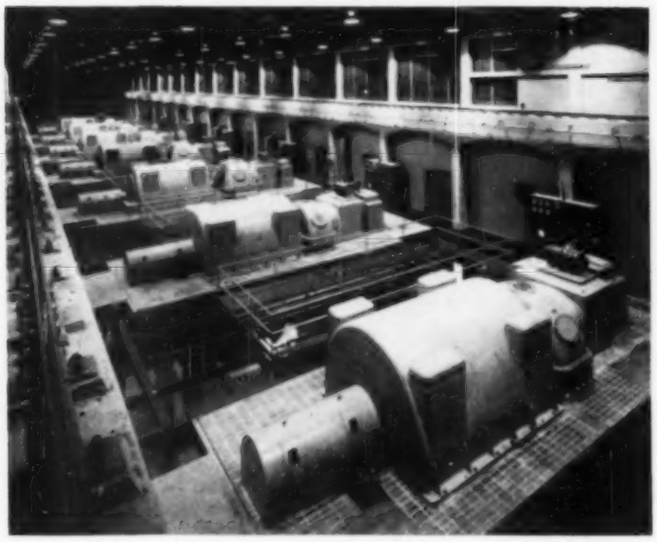

FIG. 1. Turbine-generator floor at Kaiser Aluminum Company's new Chalmette steam-electric station.

Except for its dependence on the steam plant for auxiliaries, each engine plant is independent, and includes sufficient spare capacity to maintain a high order of reliability.

The other six lines are served by ignitron rectifier equipment, two of General Electric and four of Westinghouse manufacture.

For each potline, the six or seven rectifier transformers are fed from a 13.8-kv bus, which is connected through a regulating autotransformer, to a main 13.8-kv feeder from the steam power station. The autotransformer provides voltage control of plus and minus 10 per cent, under load.

Each 5000- or 6000-amp ignitron rectifier is provided with a 6-pole high speed anode circuit breaker, a cathode circuit breaker, ignition and auxiliary equipment, and a water-to-water heat exchanger with automatic temperature control.

The master operator's panel contains control and metering for each rectifier, as well as over-all control and metering for the potline.

To provide the nearly 350,000 kva of a-c power required, and well-integrated standby services for it, the Chalmette steam station includes: twelve 25,000-kw turbine generators for the six potlines; one 25,000-kw and two 10,000-kw turbine generators for auxiliary and plant services; one 25,000-kw spare turbine generator; two 40,000-kva transformer banks for interconnecting ties to the Louisiana Power and Light's 110-kv system.

The two 10,000-kw turbine generators are assigned to one of the two plant service buses, and one of the 25,000-kw units to the other. To these two plant service buses, each of which has two symmetrical sections, there are connected several pairs of feeder circuits. These logically arranged pairs each provide alternate service to important parts of the steam plant auxiliary loads, the engine plant auxiliary loads, and the general plant services.

The twelve 25,000-kw turbine generators normally assigned to the six potline loads are connected in pairs to six "stub" buses, each of which feeds a rectifier station. The spare 25,000-kw unit's stub bus feeds the rectifier station transfer bus which is common for all six potlines.

All of the six main generator stub buses, the spare unit stub bus, the two transformer tie lines, and both of the plant service buses are connected through synchronizing reactors to the station synchronizing bus. Normally the entire station will be operated as a single completely synchronized system. The synchronizing reactors limit the fault current under this condition to less than that of the 1000-mva station switchgear. The normal load division is such that a very small transfer of power through the reactors will occur.

With this very flexible system, a maximum utility of all generating units is assured for any desired division of loading between potlines or auxiliary services, and a very high order of reliability is provided under both normal and emergency conditions. Power may be taken from or delivered to the utility system as conditions warrant.

All 14 of the 25,000-kw units are duplicate G-E turbine generators having a nominal rating of 20,000 kw, 0.85 pf, 13,800 volts, 3 phase, 60 cycles, for steam conditions of 850 psig, 900 FTT. Each turbine has a maximum capability rating of 25,000 kw; the hydrogen-cooled generators have a maximum rating of 27,000 kva, and plant capacity has been assigned on this basis. The two plant service units are G-E turbine-generators rated 10,000 kw, 0.8 pf for the same steam conditions as the main units. Fig. 1 shows a view of the turbine floor.

There are 15 Foster Wheeler gas-fired boilers with Bailey control, 14 normally serving one 25,000-kw turbine each, and one serving the two 10,000-kw turbines. A steam header system transfers steam as needed. Each turbine has a full condensing capacity Foster Wheeler surface condenser, all receiving cooling water from the river water pump house on the Mississippi River adjacent to the plant.

Facilities are provided to deliver alumina to the storage silos either from rail cars or from river barges. Alumina is delivered from Kaiser's Baton Rouge alumina plant.

When under full production, this plant will have a greater output than any other single U. S. aluminum reduction plant. It will produce all its own power, and have operating, side-by-side under duplicate conditions, the two principal d-c power supply systems in current use: steam turbine generators with rectifiers, and gas engine-driven d-c generators.

ALUMINUM COMPANY OF AMERICA, POINT COMFORT, TEXAS

The Aluminum Company of America's reduction plant at Point Comfort, near Port La Vaca, Texas, when first installed, marked the beginning of the shift of aluminum reduction to the Gulf Coast. It now has a capacity of 185 million lb per year. This plant also marked the first postwar application of gas engines to power production in this industry.

For the new Point Comfort plant, the newly developed Nordberg radial, vertical gas engine was chosen, and a carefully coordinated engine plant design was developed to make effective and economical use of the new engine's features.

Originally, three potlines were installed, and two more were added later, all of approximately 37,500-kw capacity. Each of the five engine plants has 38 or 40 Norberg engines, each driving a 1100-kw, 667-volt d-c generator.

In the design of this plant, emphasis was placed on unitizing

each engine-generator unit to an extent that, under normal operating conditions, a minimum of dependence on any common plant facilities other than the fuel gas supply and the potline bus itself, was involved. To accomplish this, several unusual features were employed.

All engine auxiliaries, except the ignition system, are separately induction-motor driven. The 400-volt, 24-cycle power for those of each engine is obtained from slip rings, mounted below the commutator on each d-c generator. All the 440-volt, 25-cycle auxiliary motors are connected directly to the slip ring supply and automatically start and stop as the engine starts and stops.

The shunt field of each generator is wound for approximately 550 volts and is self-excited from its own generator through a motor-operated rheostat. Since the generators are self-excited, the operating voltage range is limited to approximately 550 to 650 volts d-c. When the potline is in operation within this normal voltage range, any generator may readily be paralleled on the bus. For "dead line" starts, however, a 60,000-amp potline circuit breaker is used to disconnect the potline, and all generators are paralleled on the station bus at full voltage and no load. Load is applied by closing the potline breaker.

For the common station services and aluminum plant power, a number of 650 volt d-c to 4160 volt a-c motor-generator sets are operated in parallel to feed a 4160-volt distribution system from which load center substations provide 480-volt, 60-cycle plant services. This system permits all engine generators to be duplicate d-c units and makes the plant entirely self-supporting with a minimum of spare d-c units for both a-c and d-c power requirements.

Each engine is "cranked" by using its connected d-c generator as a starting motor. The field circuit is transferred to the station d-c bus for starting, and the armature is fed from the bus through a starting resistor, under normal conditions. A small gasoline engine-generator set provides starting power in emergency. Fig. 2 is a view of the engine room.

The Point Comfort plant is on the coast and receives its alumina by boat from Alcoa's alumina plant at Mobile. The use of gas engines for all power sets a new pattern in the aluminum industry. This plant's output is greater than any other of Alcoa's reduction plants except that at Alcoa, Tennessee.

Aluminum Company of America, Rockdale, Texas

The newest of the aluminum plants in the Gulf Coast area is that of the Aluminum Company of America at Rockdale, Texas. The output here will be approximately 170 million lb per year from four potlines each rated approximately 45,000 kw.

The potlines themselves and the rectifier station equipment serving them are very much the same as those of other aluminum reduction plants which use standard a-c power from whatever source.

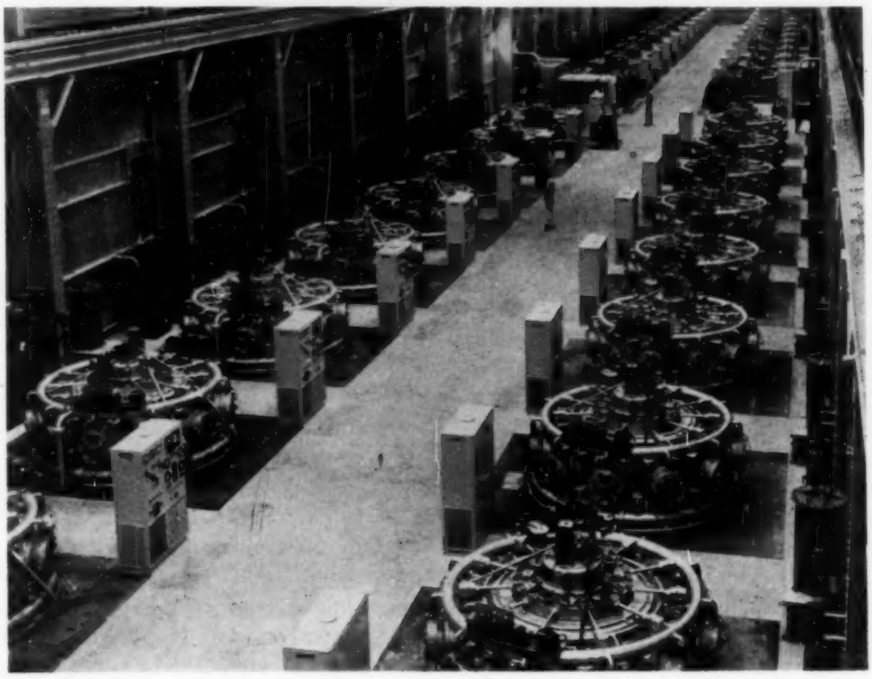

Fig. 2. Engine room at Aluminum Company of America's Point Comfort reduction plant.

Each rectifier station is served by a 13.8-kw, 3-phase, 60-cycle feeder from the power station, through a regulating autotransformer, to the normal 13.8-kv bus. This bus serves six rectifier transformers, each of which serves two ignitron rectifiers each rated 6000 amp at 750 volts d-c, providing an installed capacity of 72,000 amp and 54,000 kw per line. Two of the four rectifier station equipments are Westinghouse and two are General Electric. Each rectifier is provided with an ITE Company anode breaker and cathode breaker. Water-to-air heat exchangers, one for each rectifier, are mounted on the roof of the rectifier station.

Phase-shifting autotransformers, connected ahead of each rectifier transformer, are arranged so that each line operates 36 phase a.c., and so that associated pairs of lines operate 72 phase. From wide experience in the trade, such a multiphased system is known to be adequate and desired, to avoid communication interferences for a rectifier system of this magnitude.

Unlike the other aluminum plants of the Gulf Coast area, the Rockdale plant is not on the coast, and alumina will be delivered by rail car. This is the typical case of the reduction plant going to the power source, in this case, the abundant lignite of the Rockdale area.

The new steam-electric power plant was planned to include

substantial interconnecting ties with the Texas Power and Light system. These facilities were installed early in the program, and available power from this system has permitted the first two potlines to go into production while installation of the new plant with its lignite fuel processing facilities is being completed.

The new station will include three G-E turbine generators each having a nominal rating of 90,000 kw, 0.85 pf, and a maximum capability of 100,000 kw, 14,400 volts, 3 phase, 60 cycles for steam conditions of 1450 psig, 1000/1000 FTT, on a reheat cycle basis. Normally, all three units will operate to serve the aluminum plant and deliver additional power to the interconnected system. When a unit is out of service, the system will supply enough additional power to support full aluminum plant operation.

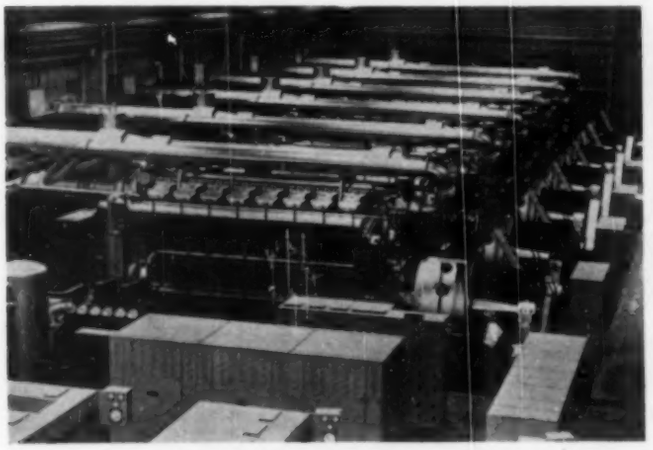

FIG. 3. A-c engine generator plant at the San Patricio plant of the Reynolds Metals Company.

The Westinghouse station switchgear, having 2500-mva air blast circuit breakers, provides a reliable station double-bus scheme, carefully integrated with current-limiting reactors, so that all three generators, the two tie transformer banks, and all feeders to the aluminum plant can be operated in parallel in any combinations desired to meet normal or emergency conditions.

It is early yet to describe or predict the performance of the lignite plant. But with large sources of lignite available in the area, this practical industrial use of it is a highly important power development, even in an area rich in gas resources.

REYNOLDS METALS COMPANY, CORPUS CHRISTI, TEXAS

The Reynolds Metals Company's San Patricio reduction plant and its adjacent La Quinta alumina plant at Gregory, Texas, near Corpus Christi, represent the area's first integrated bauxite to pig aluminum operation. The alumina plant is located on the bay where harbor facilities have been developed to receive ore boats from Reynolds' bauxite mines in Jamaica. The reduction plant will obtain its alumina directly, and more alumina will be shipped by rail to other Reynolds' reduction plants.

Each of the two potlines at San Patricio has a nominal rating of 100,000 amp at 725 volts or 72,500 kw. The ratings of all pots in the industry are steadily being increased, and these represent the furthest advance in this trend. The pots are of the Sodeberg type, and except for their size, are similar to others of the trade.

One of the potlines is powered by 33 Cooper Bessemer V-16, horizontal, four-cycle, supercharged, 327-rpm gas engines, each driving a G-E 2500-kw 725-volt d-c generator.

The other is powered by 41 General Motors 16-cylinder, vertical, two-cycle, 600-rpm gas engines each driving a G-E 2000 kw, 725-volt d-c generator.

The basic connections and entire electrical system operation of the two plants are the same. All engine and station auxiliaries are standard 60-cycle induction motor driven, served by load center unit substations, receiving power from the a-c generating station. Each generator has two d-c circuit breakers, and all 250-volt shunt fields of each line are served from either of two alternate field buses. Two alternate exciters, each with amplidyne control, are provided, either of which gives full range voltage control of the potline at any time, and permits paralleling any generator on the potline bus at no load, whatever its voltage at the time. Hence, no potroom breaker is required. The master operator has choice of: manual, automatic constant current, or automatic constant voltage control at will.

The auxiliaries for both d-c engine generator stations and approximately 6000 kva of aluminum plant power are served by a separate a-c engine-generator plant. This includes nine Cooper-Bessemer engines, essentially duplicate of those of the d-c station, except that here each drives a G-E a-c generator rated 2500 kw, 0.8 pf, 3175 kva, 4160 volts, 3 phase, 60 cycles, with a V-belt driven exciter.

The generators, in groups of three, serve three 4160-volt station bus sections, which, in turn, are normally paralleled through reactors to the station synchronizing bus. Interconnecting tie circuits are provided to the La Quinta alumina plant and to the utility system. The 4160-volt feeders are logically distributed on the three station bus sections to serve load center substations throughout the plant areas. Fig. 3 is a view of the a-c engine plant.

What Does the Future Hold?

The U. S. aluminum use for peace-time purposes is now about 2000 million lb per year, which is near the World War II peak production, and about five times that of the last pre-war year. It is forecast, with good background evidence, that U. S. power production will double in the next ten years, and many sound-thinking groups feel that aluminum production also may well do this or more. The present use of aluminum is now increasing at a rate greater than this.

It is clear that, to even a greater extent than in the past, aluminum reduction plants will seek the most economical power locations, and since much further hydro development is unlikely, this means available and economical fuel sources. So it will be with all major basic industries in the years to come.

Therefore, the future of the aluminum industry on the Gulf Coast would seem to depend upon the availability and favorable cost of increasing quantities of natural gas, and the economic success of the new lignite fuel sources, as compared with the "at-the-mine" cost of coal in other areas where it is abundant.

Aluminum production doubtlessly will expand greatly. Any area will attract it, in proportion to the answer it gives to the electrical energy cost question.

The aluminum plants of the Gulf Coast already present an imposing industrial picture, and promise one even more imposing within the next decade.

MAGNESIUM PRODUCTION IN THE SOUTHWEST

W. J. Rave[1]

During 1953 the magnesium industry in the Southwest will consume approximately 1.4 billion kwhr of electrical energy to turn out the estimated 140 million lb of magnesium which will be produced this year. With a load of 160,000 kw, magnesium production in the Southwest is an important factor in the electrolytic industries of this part of the country.

Output of magnesium during 1953 will be the highest ever attained for the Southwest, with the exception of 1943 when four plants were in operation under the stimulus of war-time demand. In the past 12 years approximately 690 million lb of magnesium have been produced in Texas and Louisiana, the majority having been extracted from sea water.

This production has occurred in four plants, two operated by The Dow Chemical Company in the Freeport-Velasco area on the Gulf Coast 60 miles south of Houston, one by International Minerals and Chemicals Corporation at Austin, Texas, and one by the Mathieson Alkali Works at Lake Charles, Louisiana. The last two of these plants were operated only during the war-time period from 1942 through 1945, and have since been abandoned.

The first production of magnesium in the Southwest occurred in January 1941, when the plant of The Dow Chemical Company at Freeport, Texas, was first placed into operation. Establishment of this new plant site and the use of an entirely new process, developed by Dow for the recovery of magnesium from sea water, typifies the confidence that The Dow Chemical Company has always had in the growth of the magnesium industry. This first plant was planned in 1938 and 1939 before the expansion accompanying World War II had started.

The availability of raw materials such as salt for the production of chlorine, oyster shell for the production of lime, and natural gas as a source of power are among the factors which prompted the establishment of the first Dow plant on the Texas Coast. This plant, originally designed for an annual capacity of 14 million lb, was promptly expanded with the assistance of the British Government to a rated capacity of 45 million lb. Within less than a year following the initial operation of Dow's original plant, capacity was expanded by the U. S. Government to a total of 36 million lb per year. This plant operated at more than 120 per cent of rated capacity during the war years.

With the outbreak of World War II and its emphasis on air warfare, it was apparent that a considerable quantity of magnesium would be required. This led to the construction of three other Government-financed plants in the Southwest. The second magnesium plant, and the largest one in the area, was built in 1942 at Velasco, Texas, seven miles from the site of the original Dow plant, with a rated capacity of 72 million lb per year. The Velasco plant, built at a cost of $56,000,000, gained considerable publicity by the fact that construction from first piling to first production took a little less than six months. This plant, operated by The Dow Chemical Company for the Government, produced magnesium successfully until its shutdown in 1945, reaching an output of over 80 million lb in 1943.

Both of these plants, one at the original Dow plant site, and the Government plant at Velasco, use the Dow process for extraction of magnesium from sea water and use the Dow Type E cell (Fig. 1) for the electrolysis of the magnesium chloride. Both the Dow process and the Dow cell have been described in the literature (1–3). The flowsheet of the Dow process is shown in Fig. 2.

The third magnesium project in the Southwest, also Government-built, was a plant located at Austin, Texas, with some of the magnesium chloride facilities being at Carlsbad, New Mexico. This plant used a part of the Dow process under license, particularly the Dow electrolytic cells. Although a chloride electrolysis plant, it was designed to use dolomitic limestone as its chief source of magnesium. It was planned that a part of the magnesium chloride, at least that equivalent

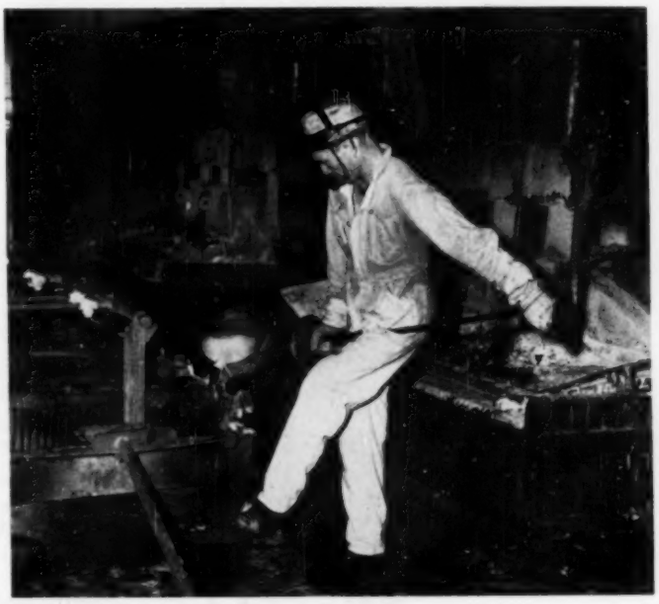

FIG. 1. Dow Type E cell used at Freeport, Velasco, and Austin plants.

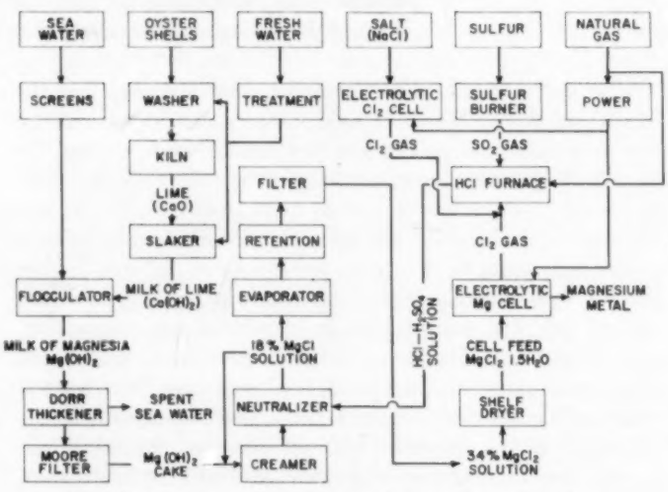

FIG. 2. Dow sea water magnesium process flowsheet

to the make-up chlorine requirements, would be recovered as a by-product of the manufacture of potash by International Minerals at Carlsbad. The Carlsbad operation was only partially successful and a substantial amount of the raw material, both in the form of a chloride and a hydroxide, was supplied by the Government's Velasco plant. The Austin plant, with a rated capacity of 24 million lb per year, operated successfully during 1942, 1943, and 1944, producing a total of a little more than 45 million lb, but was abandoned and scrapped following the end of the war. This process has also been

[1] Texas Division, The Dow Chemical Company, Freeport, Texas.

described in the literature (5, 6). Its flowsheet is given in Fig. 3.

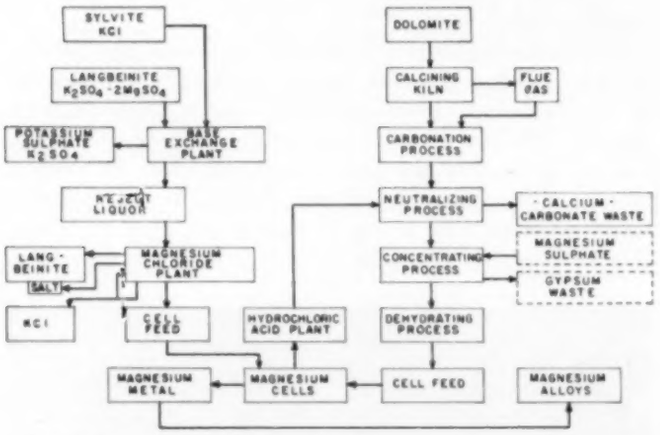

FIG. 3. International Minerals magnesium process flowsheet

TABLE I. *Magnesium production in the Southwest*

(1000's of pounds)

Calendar years	Dow Freeport, Tex.	Dow Velasco, Tex.	International Austin, Tex.	Mathieson Lake Charles, La.	Total
1941	14,269				14,269
1942	42,315	20,948	2,158		65,421
1943	43,191	80,253	25,539	2,384	151,367
1944	41,160	60,741	17,936	2,985	122,822
1945	33,653	5,262			38,915
1946	10,066				10,066
1947	24,688				24,688
1948	20,006				20,006
1949	23,195				23,195
1950	31,453				31,453
1951	42,651	18,768			61,419
1952	49,866	76,057			125,923
Total	376,513	262,029	45,633	5,369	689,544

FIG. 4. Dow Chemical Company magnesium chloride plant at Freeport, Texas

The Government plant designed and operated by the Mathieson Alkali Works at Lake Charles, Louisiana, was the fourth magnesium production installation built during the period. It had a designed capacity of 54 million lb per year, but a total production of a little more than 5 million lb was obtained and the plant was shut down and abandoned as a magnesium plant in 1944. The principal raw material for the process was dolomite stone, calcined with locally produced natural gas. The resulting oxides of calcium and magnesium were treated with calcium chloride, a product of the parent Mathieson plant in Louisiana. The mass was then treated with carbon dioxide obtained from the calcination of the dolomite, which converted the calcium into insoluble carbonate, leaving magnesium chloride. Much of the magnesium chloride feed preparation was in standard design equipment, while the electrolytic cell was one developed by Mathieson. The process and cell held some promise. Had its development been at a normal pace, it might have been ultimately successful; but under the pressure of war-time magnesium demands, an untried process was used as the basis of a full plant design. Operations were not successful and time did not permit normal growth.

A summary of the production in these four plants from 1941 through 1952 is given in Table I.

The loss of war-time demand for magnesium in 1945, and the general slump of the reconversion period, together with the magnesium scrap that had accumulated during and immediately following the war, caused the complete shutdown of all magnesium plants, including Dow's privately owned plant, in 1945. However, this complete shutdown proved

TABLE II. *Magnesium consumption, by industry uses in 1952*

(Magnesium Association)

	%
Aircraft: engines, wheels, air-frames, etc.	29.3
Aluminum industry	20.4
Electrochemical uses: underground anodes, fresh water anodes, sea water anodes, etc.	8.5
Ground transportation: trucks and trailers, automotive, etc.	7.6
Machinery and tools: portable tools, business machines	6.2
Chemical and metallurgical uses	6.0
Materials handling: dockboards and skids, foundry equipment, concrete industry, etc.	4.7
Electrical equipment: radar, radio, TV, etc.	3.5
Magnesium powder	2.4
Consumer products: ladders and hand tools, furniture, sporting goods, etc.	1.6
Textile industry	0.8
Printing and engraving	0.4
Unclassified and miscellaneous	8.6

remature and Dow's own facilities were started at a reduced te after a six-month shutdown. Production at Dow's plant s, in general, continued to increase since that date, and ll probably exceed 55 million lb in 1953.

That part of the plant at Dow's original plant site at Free- rt constructed by the British Government was purchased Dow in 1946, and the facilities constructed by the U.S. overnment were purchased, in part, in 1947; the balance as purchased in 1949. A further expansion to this plant was dded by Dow in 1952, giving a total capacity of approxi- ately 59 million lb in Dow's privately owned plant at Free- rt.

The Velasco plant, built by the Government, was shut down ith the rest of the plants in the area in 1945, but on the ecommendation of the Symington Committee, this plant, gether with six other Government-owned magnesium plants ot including the Austin and Lake Charles plants), was re- ained by the Government as a part of the National Indus- ial Reserve. The Velasco plant was maintained in a stand-by ondition by the Government from 1945 through 1950 and as returned to operation in 1951. The plant is now being perated for the Government by The Dow Chemical Company nder a lease agreement to supply magnesium for the national tock pile and for the current armament program. Although riginally rated at 72 million lb, the Velasco plant has con- istently operated above rated capacity and is generally listed s having a capacity of 80 million lb per year at the present ime, giving the combined Freeport and Velasco plants a ated capacity of 140 million lb.

In at least two aspects, magnesium production in the South- est is unique among the primary metals. First, magnesium s one of the few primary metals produced on a closely inte- rated basis with the chemical industry. Chemicals have been roduced as by-products in the production of aluminum, teel, and other metals, but because of the chemistry in- olved in the chloride process, magnesium production and production of chemicals strengthen each other on raw mate- ials, by-products, etc.

Second, magnesium is the only primary metal being eco- nomically produced from an unlimited ore supply available domestically. Other metals are now being produced from ore bodies which may be exhausted in the foreseeable future. This exhaustion of the higher yield domestic ores will require that many of our primary metals be derived from lower grade or overseas deposits. The magnesium content of the ocean waters of the world has been estimated to be 2×10^{15} tons, which, for all practical purposes, is an inexhaustible supply. This abundance of raw materials led the Paley Commission to the conclusion that magnesium production might increase from 20,000 tons in 1950 to a possible high of 1,000,000 tons in 1975 (7).

It has frequently been pointed out that these two unique factors in magnesium production both favor long range sta- bility in magnesium costs. Emphasis on probable price sta- bility has at times neglected the fact that the costs of many materials and services such as power, graphite, plant construc- tion, and labor involved in the production of magnesium, have risen more rapidly over the past ten years than has the price of magnesium. This is particularly true of the power costs in the Southwest which have risen sharply as natural gas has been piped in increasing quantities to other parts of the United States. The net result appears to be that, while abundant raw materials will act as a long range stabilizing influence on the magnesium cost, the market price of mag- nesium should be expected to adjust to its proper relationship to the general commodity index.

The recent Government order shutting down five of the six Government plants which were placed in operation in 1951 leaves all of the magnesium production in the United States concentrated in the Southwest, with the exception of a small amount of magnesium produced on a captive basis for use in titanium production. Not only is all the nation's commercial magnesium production concentrated in the Southwest, but a preponderance of the world production as well. Although the American Southwest should continue to be a major factor in the magnesium industry, we cannot expect to maintain our exclusive position. Electrical power and natural gas are neither as cheap nor as readily available as was the case 15 years ago, and the combination of power and sea water or other raw materials, such as underground brines, are available else- where. Strategic considerations also indicate that the produc- tion of primary magnesium should not be too highly concen- trated in one locality. Although the Southwest may not maintain its exclusive position in the magnesium production, it will be a dominating factor for many years to come.

On a national scale, magnesium consumption promises to grow and expand. Consumption of primary magnesium, which amounted to 40 million lb in 1950, is projected at approxi- mately 90 million lb for 1953 and 160 million lb for 1959.

New applications for magnesium, both in the structural and in the chemical and metallurgical fields, are being found, and those connected with magnesium are optimistic that its growth, both nationally and in the Southwest, will continue.

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ELECTROCHEMICAL CHLORINE-CAUSTIC SODA PRODUCTION IN THE GULF COAST AREA

Frank Chrencik[1]

Well in step with the vast, rapid growing, chemical industries of the Gulf Coast area is basic and essential chlorine, with its co-products of caustic soda and hydrogen, or elemental sodium in lieu thereof. Abundance of salt in many scattered and practically inexhaustible salt domes is attractive to chlorine producers in itself, but when enhanced with abundance of natural gas, sulfur, petroleum, sea water, iron, coal, lime, and agricultural products, a sound, diversified, chemical industry is readily visualized. All salt sources for the 11 chlorine manufacturers in the Gulf Coast area are from domes formed through a prehistoric, geological phenomenon so that deeply underlying salt strata have been forced sufficiently close to the surface to permit access by drilling and dissolving. All chlorine producers in the Gulf Coast area, with the exception of the Ethyl Corporation, have captive salt deposits from which brine requirements are obtained. Current rate of salt usage from the widely scattered salt domes is estimated at present at 6100 tons per day.

The Gulf Coast area, which affords the American dreamer of a chemical empire his best opportunity to succeed today, is along the Texas, Louisiana, and Alabama coast line, at an inland distance of usually less than 50 miles. While producers of chlorine find the majority of their chlorine consumed within a comparatively small radius of their works, over 95 per cent of the chlorine produced within the area is consumed therein. Railroads, inland waterways, and the Gulf provide a strategic point of origin for export as well as domestic shipping. Not to be ignored is also the ever increasing pipeline method of transporting, not only chlorine but numerous basic chemicals, petroleum, and gas products. Perhaps the oil industry deserves credit for pointing the way. The Diamond Alkali Company, for example, ships substantial quantities of chlorine, caustic soda, and hydrogen by this method. The newness of the area presents the advantage of having plenty of space for industrial expansion and pipeline easements, which might not be the case in the saturated Northern industrial developments.

Growth of the Chlorine Industry

Prior to World War II, the Gulf Coast area requirements for chlorine and caustic soda were satisfied with a few hundred tons per day, with approximately 100 tons being shipped to consumers and the balance used captively by The Dow Chemical Company and Ethyl Corporation as the primary, captive chlorine users at that time. Solvay and Southern Alkali (now Columbia Southern Chemical Corporation) produced most of the chlorine sold as such. The Gulf Coast area now lists the following producers of significance at the indicated locations. It will be noted that all of these manufacturers, with the exception of Frontier Chemical, located in the northwestern part of Texas, are in close proximity of the Gulf Coast.

Dow Chemical Company, Freeport, Texas
Ethyl Corporation, Baton Rouge, Louisiana
Ethyl Corporation, Pasadena, Texas
Solvay Process Company, Baton Rouge, Louisiana
Diamond Alkali Company, Pasadena, Texas
Columbia Southern Chemical Corporation, Lake Charles, Louisiana
Columbia Southern Chemical Corporation, Corpus Christi, Texas
Champion Paper & Fibre, Pasadena, Texas
Mathieson Chemical Corporation, McIntosh, Alaba
Frontier Chemical Company, Denver City, Texas
Gulf Oil Corporation, Port Arthur, Texas

These producers represent a presently combined, dai chlorine production capacity of 3210 tons of chlorine, whi also reflects a total electrolytic, caustic soda capacity of 32 tons, plus 220 tons of elemental sodium (Ethyl Corporation and 29 million cubic feet per day of hydrogen. Fig. 2 shows th chlorine producing plants in the Gulf Coast area. Thus th production of chlorine has increased from about 520 tons p day in 1943 to 3210 tons in the current year, 1953. The ind cated, better than sixfold increase over the past decade ha placed these chlorine plants in the position of producin about 30 per cent of the nation's entire production, with Tex alone producing about 22 per cent of the nation's supply The Dow Chemical Company contributes a large portion t both of these percentages.

Upgrading of Products

The upgrading of basic and intermediate chemicals cap tively has been a foremost subject in chemical manufacturi circles throughout the nation. Foremost in this trend is Th Dow Chemical Company, with Diamond Alkali Compan moving strongly in this direction. Ethyl Corporation has al ways maintained captive chlorine and sodium capacity as a prerequisite to tetraethyllead manufacturing, but also has i recent years expanded to other products involving chlorine For those producers who sell chlorine as such, more than likel this chlorine is being shipped a comparatively short distanc to a purchasing plant which furnishes other captive materials such as hydrocarbons. It seems that the petroleum industry favors the term "petrochemicals" when they are the users o purchased chlorine and caustic soda for captive upgrading o their hydrocarbons. The captive chlorine users, on the othe hand, seem to favor terms such as "organic chemicals," "chlorinated hydrocarbons," etc. To date, there seems to be no definite indication as to which of these two basic types o industry can claim a closer position to the end-item consume market and the stages of profit taking involved. Perhaps the third basic type of industry, such as Union Carbide and Celanese, who purchase most of their basic chemicals, enjoy this distinction, at least for the present. Captive users o chlorine and caustic soda are now producing such products as plastic monomers and polymers, solvents, pharmaceutical intermediates, detergents, organic insecticides and herbicides, fuel additives, refrigerants, etc. Dow, Diamond, and Ethyl are particularly active in these fields. Each of these basic categories of products includes many types which are continually increasing in variety and application. This type of demand for chlorine clearly indicates the trend toward increased usage of chlorine for chemicals in relation to the older applications such as pulp and paper, sanitation, and textiles. The past ten years have seen chlorine demand for chemicals produced in the Gulf Coast area rise from about 70 per cent of total chlorine production in 1943 to over 90 per cent of current chlorine production, this notwithstanding the fact that there has been over a sixfold increase in capacity during the past ten years.

The Problem of Co-product Disposal

While chlorine capacity expansion has in most cases caused a corresponding increase in caustic and hydrogen, the demand

[1] Diamond Alkali Company, Pasadena, Texas.

for these co-products has not increased as well; however, local demand and export facilities to South American markets, in particular, have maintained a more balanced picture as compared to other areas. The petroleum industry in itself is a very substantial consumer of caustic soda, in that caustic is involved in many phases of petroleum processing, beginning with caustic required for the mud used in oil drilling operations and, finally, in the sweetening process in finished gasoline treatment. Caustic soda is produced in a number of forms such as standard, 50 per cent, commerical, 70 per cent, and in a number of anhydrous forms, such as solid, flake, and powder. A notable advancement in the fusion of caustic to anhydrous form is illustrated by the dowtherm-heated, evaporative type of process used for this purpose by the Diamond Alkali Company and Columbia Southern. Very substantial advantages have been realized by this revolutionary change from the conventional, cast-iron, fusion pots to the dowtherm-heated evaporative arrangement.

FIG. 1. View of surplus salt storage and brine treating facilities of the Diamond Company. Brine treatment for removal of impurities is an important prerequisite prior to the electrolysis of brine.

Hydrogen markets have had very little influence on the economic justification for a chlorine plant, but it is worthy of mention in that hydrogen is becoming recognized as a co-product of value. It is enjoying increasing demand to the extent that the electrolytic process of decomposing salt is pointing to a three-component output of salable products, in lieu of two customarily recognized as chlorine and caustic soda. Ammonia, anhydrous hydrochloric acid, and hydrogenation of unsaturated hydrocarbons are examples of present day hydrogen usage.

Electrolytic Cells

Electrolytic cells used among the Gulf Coast chlorine manufacturers are as varied as in any other part of the nation, perhaps even more so in view of the fact that many plants have adopted a design-and-build-your-own policy. Capacity trends in the cell designs have also increased very substantially in the past ten years, in that a 10,000-amp cell in 1943 was considered very substantial indeed. Present day cell capacities of 20,000–30,000 amp are not uncommon. Cell designations used among the local chlorine manufacturers are such as Hooker S-3, the Dow Cell, the Diamond Cell, Allen Moore, and the Downs Cell in case of chlorine-sodium production at Ethyl. The area, at present, claims only one mercury cell installation, and that is the Mathieson Cell being used in the Mathieson Chemical Corporation's new chlorine plant at McIntosh, Alabama. Enthusiasm for the mercury cell, following access to European technology of this type, has not been appreciably felt in the Gulf Coast area. There are many factors to consider in choosing between the two basic types of electrolytic cells, namely, diaphragm and mercury. It is known that the mercury cell produces a more pure grade of caustic than electrolytic cells do; however, the type of caustic usage involved in the Gulf Coast area has been satisfied with electrolytic quality. In such cases where quality demands must be met for specialized application, it appears that the electrolytic caustic can be purified satisfactorily. Another consideration is the captive power generation that exists among the chlorine producers. This arrangement provides manufacturers with a cheap source of process steam for evaporation of cell liquor from electrolytic cells, whereas mercury cell users usually purchase power from outside sources and make commercial caustic strength directly off the cell without the necessity of subsequent concentration in steam heated evaparators. What the ultimate size and capacity of the various electrolytic cells employed will be eventually is difficult to forecast, as fairly intensive research and development work is directed toward increased capacity per unit cell and thereby reducing building and other facility requirements to house the increasingly concentrated output of such electrolytic equipment.

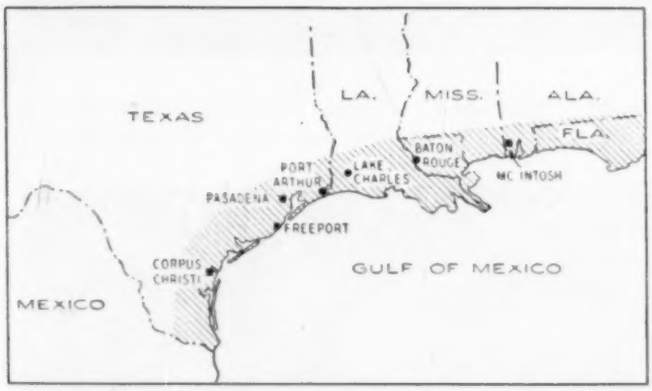


FIG. 2. Chlorine producing plants in the Gulf Coast area. Columbia Southern Chemical Corp., Corpus Christi, Texas, and Lake Charles, La.; Dow Chemical Co., Freeport, Texas; Diamond Alkali Co., Pasadena, Texas; Champion Paper & Fiber Co., Pasadena, Texas; Ethyl Corp., Pasadena, Texas, and Baton Rouge, La.; Solvay Process Co., Baton Rouge, La.; Gulf Oil Corp., Port Arthur, Texas; Mathieson Chemical Corp., McIntosh, Ala.

Power Supply

The chlorine industry in this area generates approximately 70 per cent of its power requirements, or approximately 7,200,000 kw per day. Many factors enter into a decision as to whether captive power generation is justified as compared to purchase from a public utility. Perhaps one of the most determinant factors is the requirements for steam which can be extracted from power-generating turbines. In the case of a public utility, the latent heat from steam must be condensed after the turbine and discarded with the condensing water without further benefit. This same heat, representing over 60 per cent of energy iuput to the turbine, can be utilized to material advantage in a chemical processing arrangement,

particularly one that utilizes diaphragm cells where 10–12 per cent caustic soda liquor must be concentrated to 50 and 70 per cent strength. With the huge influx of electrochemical industries to the Gulf Coast area, the public utility system could not originally meet these sudden demands and public utility power has been in quite critical shortage until recent months when very substantial expansion on the part of public utilities has accorded appreciable relief to the general Southwest area power shortage and left an improved outlook for future supply for those who contemplate additional power requirements in the future.

Outlook for the Future

There are still substantial quantities of undeveloped resources in Texas. This, combined with climate, geography, and the anticipated influx of population, contributes to a picture of future growth. Manufacturers of consumer end-items have very little direct dependency on natural resources and consequently they are somewhat slower in realizing the benefits of this new industrial area. Many well-established Northern industries will pay the penalty of high transportation costs for materials from the South and maintain the advantage of operating with previously established facilities, or even expanding them, and being located closer to the center of the United States population. A favorable tax situation for Gulf Coast industries has been preserved to date; however, state legislatures are continuously scrutinizing the conspicuously new industrial activity as a potential source of increased revenue. Potential plants have this economic discouragement to be concerned with. State, county, and school districts tax revenue has been materially enhanced by industries through normal taxation already and an added tax burden against the basic industries specifically may well be the cause of the death of the goose that is laying the golden egg.

POWER FOR GULF COAST ELECTROCHEMICAL PLANTS

H. Lee Norris, Jr.[1]

The history of the electrochemical industry along the arc of the Gulf Coast extending roughly from Corpus Christi, Texas, to New Orleans, Louisiana, is a brief one in regard to years. The development of the power plants which, of course, has paralleled the electrochemical industry, has been marked by mammoth-sized installations. As the growth of the electrochemical industry along the Gulf Coast has been unparalleled, so also has the growth of the power-producing facilities.

The two chief features that the power plants serving electrochemical installations have in common are, with one notable exception, that they all burn gas and, in design, they are generally unconventional.

The reserves of natural gas available in this area have been unprecedented both in size and in number of fields, and, until only a few years ago, they had no sizeable market. Growing general industrial activity, the tremendous growth of the electrochemical industry, and the development of the network of large-diameter, interstate pipelines have given this gas a market and have occasioned a rapid rise in market price, which leads some people to predict a gas shortage in the Gulf Coast area. Whether or not a shortage develops will depend primarily on the rate of discovery of new gas reserves and upon the price of natural gas relative to other fuels. Some authorities predict that in the not too distant future, the price of gas on a heat-content basis will approximate the cost of petroleum residium or other petroleum fuels on a heat-content basis. The reflection of this thinking may be seen in the Rockdale works of the Aluminum Company of America which has been designed around lignite fuel.

There follows in this article the principal data of the power plants for the electrochemical industry. For various reasons it is not feasible to estimate the cost of generating power for individual plants.

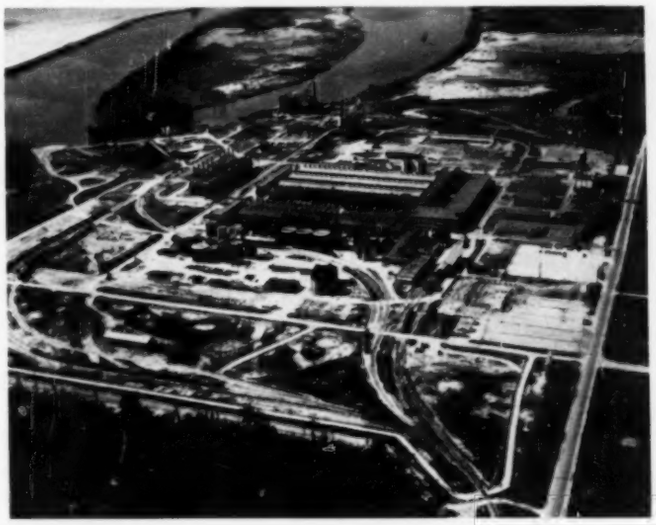
Brief descriptions of an engine plant and steam plants are included to show the contrast between the types of construction. None of these plants can be considered conventional, as in some respects they have all deviated, some slightly and others greatly, from the usual means of generating power. In all cases, the load factor is as nearly unity as the operating and maintenance skills of the various companies can make it approach unity. In fact, it is something of a salient industrial achievement for these plants to come as close to unity load factor as they do.

Climate, also, has influenced the design of the plants almost as much as the type of fuel and of load, because in no case is a power installation completely enclosed in a conventional building. In all cases, the engine plants have the engines and generators located inside buildings, but the buildings themselves, instead of being the massive masonry structures usually associated with power production, are of light-weight, steel frame sheet-aluminum construction. All of the steam plants have either one boiler, all the boilers, or all the boilers and turbines located outdoors.

In the Gulf Coast area, where temperatures below freezing normally exist less than fifty hours per year and where rain is likely to come in tropical downpours followed by extended periods of dry weather, outdoor construction has been thoroughly proved. Weather interferes very little with heavy maintenance in outdoor installations because the extreme reliability of modern steam generators and steam turbines makes major overhaul an infrequent operation.

[1] The Fish Engineering Corporation, Houston, Texas.

Summarized in Table I are pertinent data relative to Gulf Coast electrochemical power-generating facilities; it does not take into account energy purchased from the local utility networks. Many of the Gulf Coast electrochemical plants have substantial utility interconnections and these are called upon to furnish sizeable blocks of power depending upon availability of such power from the network, outages of the electrochemical industries' own generation equipment, and the urgency of demand for the products.



Aerial view of Columbia-Southern Chemical Corporation's plant at Lake Charles, Louisiana.

Individual engine control panels and motor-generator sets shown here are in one of the five engine rooms of the Aluminum Company of America plant at Point Comfort, Texas.

There is some hydroelectric generation of power in Texas, although its total is small in comparison with the generating capacity by thermal-power plants. Some of this hydroelectric energy finds its way into electrochemical production through utility interconnections.

The Dow Chemical Company, Freeport, Texas

The first electrochemical plant of magnitude on the Gulf Coast was that of The Dow Chemical Company at Freeport, Texas, and reference to Table I shows it to have the largest generating capacity of any of the companies described. Proper description of the various installations for producing power at The Dow Chemical Company plant should be the subject

TABLE I. *Summary of Gulf Coast electrochemical power generating facilities*

Names / Locations	Alcoa Rockdale	Am. Smelt. & Ref. Corpus Christi	Columbia-So. Corpus Christi	Columbia-So. Lake Charles	Diamond Alkali Houston	Dow Chem. Plant 1 Freeport	Dow Chem. Plant 2 Freeport	Dow Chem. Plant 3 Freeport	Alcoa Point Comfort	Reynolds Metals San Patricio
Number of units	3	3 a.c. 5 d.c.	5	8	3	7	5	3	194	9 a.c. 74 d.c.
Kw rating of units	100,000	2000 & 5000 a.c. 2500 d.c.		7500 to 15,000	10,000	3–10,000 3–20,000 1–30,000	1–35,000 2–40,000 1–45,000 1–60,000	3–40,000	1100/1200	2500 a.c. & d.c. 2000 d.c.
Total kw rating	300,000	21,500	37,500	70,000	30,000	120,000	220,000	120,000	228,000	187,000
Turbine steam pressure psig	1,450	400	850 & 400	400	850	400	1250 & 235	1250	Gas engine	Gas engine
Turbine steam temperature	1005°F	750°F	825°F & 700°F	750°F	900°F	750°F	900/575°F	950°F	Gas engine	Gas engine
Generated voltage	14,400	2300 a.c. 500 d.c.	13,800 & 2,300	13,800	13,800	13,800	14,400	13,800	667 d.c.	4160 a.c. 725 d.c.
Rectified voltage	750	500	600/700	650	645	800 max.	800 max.	800 max.	None	None
Type rectifiers	Hg arc	Hg arc	Hg arc		Hg arc	Hg arc	Hg arc	Hg arc	None	None
Process steam pressure	None	75 psig	400; 140 & 15 psig		150 & 18 psig	400; 150 & 30 psig	450; 235 & 30 psig	400; 150 & 30 psig	None	None
Turbines (location)	Outdoor	Indoor	Indoor		Indoor	Indoor	Indoor	Indoor	None	None
Boilers (location)	Outdoor	3 Indoor 1 Outdoor	2 Outdoor 3 Indoor		Outdoor	Indoor	Indoor	Outdoor	None	None
Fuel	Lignite	Nat. gas	Nat. gas	Nat. gas	Nat. gas	Nat. gas	Nat. gas	Nat. gas	Nat. gas	Nat. gas
No. kw installed by years from 1940	Being installed at present	1942—16,500 1951— 5,000	1941— 7,500 1952—30,000		1948—30,000	1941—70,000 1942—20,000 1951—30,000	1942—120,000 1951— 40,000 1953— 60,000	1952—80,000* 1953—40,000	1949—132,000 1951— 96,000	1952—187,000
Total generation 1952 mwh		164,955	942	565,000	288,000	1,095,000	1,377,000	67,000	1,230,814	Partial year
End use of power	Al	Zn, Cd, & H_2SO_4	Cl_2		Cl_2 & caustic	Cl_2 & Mg & plant utility	Cl_2 & Mg & plant utility	Cl_2 & Mg & plant utility *No. 1 Nov. 1 No. 2 Dec. 12	Al	Al

of an entire list of papers describing this installation which has many unique features. The original installation, made in 1939, was built around generating steam at 400 psig, 750°F total temperature, and used extracted steam in order to achieve the best practicable heat balance. In all plants the minimum amount of steam is condensed and sea water from the Gulf of Mexico is used for cooling water.

The evaporation of caustic soda is the largest use of process steam and its use, up to moderately high pressures in the synthesis and processing of organic chemicals, is very extensive. Most of the electric energy is used for chlorine-caustic and magnesium production, with a relatively small amount required for lighting, pumping, etc.

The Dow power production takes place in three separate plants, electrically interconnected, each of which is designed to meet a definite need with available equipment at the time of design. This accounts for the wide difference in their design features. In fact, Plant B is probably the only power plant ever built with a "topping" turbine being installed during the original construction.

American Smelting and Refining Company, Corpus Christi, Texas

The Corpus Christi plant of the American Smelting and Refining Company produces zinc and cadmium by the electrolytic process and generates the necessary power in a steam power plant producing both direct and alternating current. The a-c generators are of the conventional type and were manufactured by Westinghouse Electric Corporation. D-c generating sets, also of Westinghouse manufacture, consist of a turbine, reduction gear, and a double armature d-c generator, the armatures being placed back to back which places the commutators on each end of the rotor. A part of the direct current is generated and load balance is achieved by the use of one 2500-kw Allis Chalmers mercury arc rectifier.

Steam is produced at 400 psig and 750°FIT. Three of the boilers are located inside the brick power-plant structure and the new boiler presently being installed is a semi-outdoor installation. The firing aisle is enclosed as an extension of the building. Circulating water is provided by conventional mechanical draft cooling towers located adjacent to the building. The plant is entirely functional in its design, there being no fuss or frills. To provide power for an expansion program now underway at Corpus Christi, the American Smelting and Refining Company has arranged to purchase up to 10,000 kw from Central Power and Light Company and rectify it at 600 volts with mercury arc rectifiers for additional zinc production.

Reynolds Metals Company, San Patricio Works

The San Patricio Works is located near Corpus Christi, Texas, and all direct current for the reduction of aluminum is generated at the works by spark-ignited gas engines driving d-c generators.

Two types of engines are used: Cooper-Bessemer LSV-16 cylinder horizontal exhaust-gas, turbo-charged engines and General Motors 16-358X vertical engines. Each engine has 60-cycle a-c motors driving its lubricating pump, jacket water pump, fan, and scavenging blower in the case of the General Motors engine. The jacket water and lubricating oil are cooled by fan-blown, extended-surface heat exchangers just outside the building. Two speed motors are used for temperature regulation of jacket water and lubricating oil running at either high or low speed according to the weather.

The a-c power to drive auxiliaries as well as for general use is generated by nine Cooper-Bessemer LSV-16 engines driving 2500-kw a-c generators.

There are three power houses: one, housing 33 Cooper-Bessemer LSV-16 engines for d-c production; one, housing 41 General Motors 16-358X engines for d-c production; and one, housing 9 Cooper-Bessemer LSV-16 engines for a-c production. In addition to generating facilities, the a-c power house contains distribution load centers and an 8-cylinder LeRoi engine driving a small alternator for dead starting purposes. After starting, each a-c unit's auxiliaries are driven by the a-c power generated by that unit which requires an auxiliary transformer for each a-c unit. This gives the maximum of reliability.

The Cooper-Bessemer engines are air-started in the conventional manner and the General Motors engines are started by motoring the generator on the bus.

The buildings are steel frame with corrugated aluminum siding and each has an overhead crane. In the case of the horizontal engines, the buildings are of one-story construction and for the vertical engines, they are of two-story construction. The vertical generators are on the first floor and the engines are on the second. The generators are surrounded by a steel plate cylinder which supports the engine.

A large amount of ventilating air is required for the buildings, as all generators are self-ventilated. Each engine has as one of its auxiliaries a ventilating fan to supply and distribute its proportional amount of ventilating air.

All generators, switch gear, and load centers are of General Electric Company manufacture, and the d-c buses are aluminum bars.

Almost 1,800,000 kw of installed generating capacity are devoted to the electrochemical industry on the Gulf Coast area. This is an impressive total and is almost certain to become much greater within the next few years.

Acknowledgment

The author appreciates information in this article that was made available to him by the Aluminum Company of America, American Smelting and Refining Company, Columbia-Southern Chemical Corporation, Diamond Alkali Company, The Dow Chemical Company, and the Reynolds Metals Company.

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Feature Section

The Mechanism of Electropolishing of Copper in Phosphoric Acid Solutions

I. Processes Preceding the Establisment of Polishing Conditions

J. Edwards[1]

ABSTRACT

An equation due to Elmore relating the time required to establish polishing conditions to the current applied has been tested with a copper anode in phosphoric acid. The dependence of a constant in Elmore's equation on anode area, phosphoric acid concentration, copper solubility, viscosity, and copper concentration has been investigated. The results show that the process is diffusion-controlled but that Elmore's hypothesis, that the onset of polishing coincides with the attainment of the solubility limit of copper in the electrolyte, is incorrect, since additions of copper to the electrolyte were found to have no effect on the constant, except insofar as they modified the viscosity. Two possible explanations of these results are advanced, based on the view that the controlling process is depletion of the anode layer with respect to either hydrogen ions or to those ions or molecules with which the copper ions are combined in the solution. It is shown how the latter interpretation can explain the principal features of electropolishing.

Introduction

The object of this investigation was to seek the mechanism of electropolishing of copper in phosphoric acid solutions by establishing, first, what conditions prevail at an anode undergoing polishing and, second, how such conditions produce (*a*) suppression of crystallographic etching and (*b*) smoothing.

The processes which occur in an electropolishing cell prior to the establishment of polishing conditions received quantitative treatment by Elmore (1).

On the assumption that the onset of electropolishing coincides with the attainment of the "solubility limit" of metal in solution at the anode surface, he derived from the simple diffusion equation the following relation between the applied current, i_o, and the transition time taken to establish polishing conditions, t_o: $i_o t_o^{\frac{1}{2}} \frac{1}{2} c_m A \mathbf{F} (\pi D)^{\frac{1}{2}}$ = constant, where c_m is the solubility limit of the metal in the electrolyte, A is the area of the anode, D is the coefficient of diffusion of dissolved metal, assumed to be constant, and $\mathbf{F}$ is the faraday.

With a copper-orthophosphoric acid cell, Elmore showed $i_o t_o^{\frac{1}{2}}$ to be very nearly constant in each of six concentrations of orthophosphoric acid, the mean value falling from 2.72 at sp gr 1.200 to 0.7 at sp gr 1.600. No attempt was made, however, to relate the value of the constant to c_m, A, or D.

The present paper describes studies of the dependence of $i_o t_o^{\frac{1}{2}}$ on anode area, phosphoric acid concentration, copper solubility, viscosity, and copper concentration. Determinations have also been made of $i_o t_o^{\frac{1}{2}}$ for solutions having different phosphoric acid and copper concentrations but approximately the same viscosity. The results show that the process is diffusion-controlled. However, since the presence of large amounts of dissolved copper in the electrolyte was found not to modify $i_o t_o^{\frac{1}{2}}$, provided that allowance was made for viscosity changes, Elmore's view that the onset of polishing coincides with the attainment of the solubility limit of copper in the electrolyte cannot be true. Possible alternative mechanisms are discussed. The avoidance of etching under polishing conditions is explained as due to the suppression of the effect of slight potential differences on the anode surface. This was tested by experiments with a composite anode.

[1] British Non-Ferrous Metals Research Association, London, England.

Experimental

Cell and Circuit

The cell used for the determination of $i_o t_o^{\frac{1}{2}}$ is shown in Fig. 1. The anode was the end face of a copper rod, covered at the sides with rubber tubing and fitted with a small glass shield to insure uniform current distribution and diffusion across a plane of known area, while reducing convection to a low value. In order to maintain a fairly constant resistance in experiments with different sizes of anode, the height of the shield (½ in. for the ¼-in. diameter anode) was made approximately proportional to the anode area. The cathode was a cylindrical piece of copper foil. The cell, containing 150 ml of electrolyte, was immersed in a thermostat at 25°C. Before any determinations were made a small amount of copper was always dissolved into the electrolyte by allowing the anode to electropolish for 15 min. Between each t_o determination, the solution was thoroughly stirred then allowed to settle.

Current was supplied to the cell from high tension batteries through a series resistance of about 3,600 Ω, different voltage tappings being used to provide different currents. During each t_o determination the current was kept steady by slight adjustment of the series resistance. The arrangement permits a considerable potential rise at t_o and consequently vigorous oxygen evolution which Elmore avoided. This, however, is no disadvantage in a study confined to processes occurring during the transition period.

Preparation of Solutions

The concentration of phosphoric acid is expressed as percentage by volume of concentrated acid (sp gr 1.71). Solutions containing dissolved copper were prepared in some cases by addition of copper phosphate, but more usually by dissolving copper anodically from a bar of pure metal con-

tained in a porous pot. Solutions of the desired viscosity were obtained by mixing solutions in water and in glycerol, each of the required concentration.

Determination of the Solubility of Cu^{++}

Copper was dissolved anodically to give slightly supersaturated solutions. After standing at 25°C for some months, the solutions were filtered and the Cu^{++} estimated electrolytically.

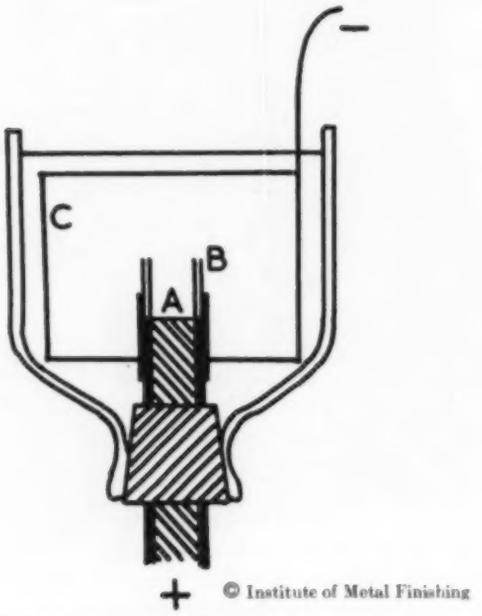

FIG. 1. Cell. A, anode; B, glass shield; C, cathode

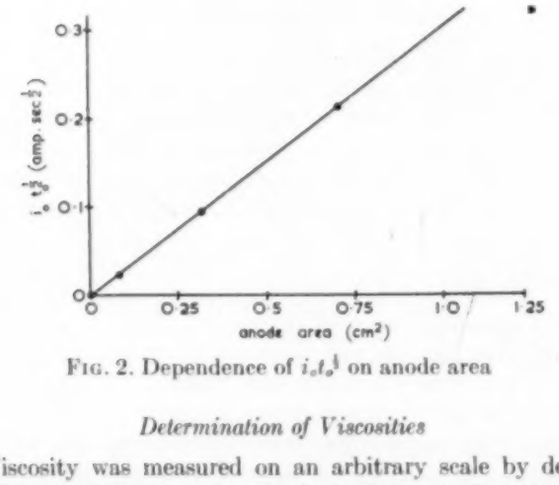

FIG. 2. Dependence of $i_o t_o^{\frac{1}{2}}$ on anode area

Determination of Viscosities

Viscosity was measured on an arbitrary scale by determining the time taken for 20 ml of solution to flow through a standard capillary tube immersed in a thermostat at 25°C. The solution reservoir was fitted with a constant head device which was adjusted to make the head inversely proportional to the specific gravity of the solution under test.

Results

To insure that the metal dissolved anodically could be equated without error to the current passing through the cell, the loss in weight of a copper anode was compared with the gain in weight of the cathode of a copper coulometer in series. At voltages below that corresponding to visible gas evolution, the dissolution of copper as Cu^{++} was found to proceed with complete efficiency.

Constancy of $i_o t_o^{\frac{1}{2}}$

Within the range of conditions investigated, $i_o t_o^{\frac{1}{2}}$ was found to be nearly independent of i_o for a given cell, although there was a tendency for $i_o t_o^{\frac{1}{2}}$ to be slightly greater than the mean (5% maximum for ¼-in. diameter anode) at the highest and lowest values of t_o.

Dependence of $i_o t_o^{\frac{1}{2}}$ *on Anode Area*

For anodes of diameter ⅛, ¼, ⅜, and ½ in., $i_o t_o^{\frac{1}{2}}$ was determined in 75 per cent phosphoric acid at 25°C. The mean values are plotted against anode area in Fig. 2. The points fall on a straight line, which passes through the origin; this confirms that $i_o t_o^{\frac{1}{2}}$ is proportional to A. There is a discrepancy with the largest anode which cannot readily be accounted for and in view of this the ¼-in. diameter anode was used in subsequent experiments.

Dependence of $i_o t_o^{\frac{1}{2}}$ *on Phosphoric Acid Concentration, Solubility of Copper, and Viscosity*

The mean values of $i_o t_o^{\frac{1}{2}}$ for phosphoric acid solutions of concentrations between 30 and 100 per cent by volume are given in Table I.

The decrease in $i_o t_o^{\frac{1}{2}}$ with increasing acid concentration confirms the result obtained by Elmore who states that this "is to be expected, for the solubility limit, c_m, of copper should be less when there is more acid present." The meaning of the term solubility limit is not clear, but, although it may not

TABLE I. $i_o t_o^{\frac{1}{2}}$, Cu^{++} *solubility and* η *for phosphoric acid solutions*

Phosphoric acid % by vol	$i_o t_o^{\frac{1}{2}}$ amp $sec^{\frac{1}{2}}$	Solubility of Cu^{++} g/l	η sec/20 ml	$i_o t_o \eta^{\frac{1}{2}}$
30	0.240	114	31.7	1.35
40	0.210	120	42.4	1.37
50	0.174	106	54.9	1.29
60	0.133	96	81.6	1.20
70	0.099	84	125	1.11
80	0.071	72	191	0.98
90	0.051	—	315	0.91
100	0.036	—	513	0.82

perhaps be identified with the normal bulk solubility, it is not unreasonable to assume that the two are related.

Approximate figures for the solubility of copper are set out in the third column of Table I. At concentrations of phosphoric acid greater than 80 per cent, the rate of dissolution of copper was so slow that it was not possible to prepare satisfactory solutions. Even allowing for the possibility of a fairly large error in the solubilities, it is clear that no direct relationship exists between $i_o t_o^{\frac{1}{2}}$ and the solubility of copper. One probable reason for this is that Elmore assumes D, the diffusion coefficient, to be constant. However, the solutions differ greatly in viscosity and this must be accompanied by a variation in the diffusion coefficient. For a spherical particle of radius r in a medium of viscosity η, the Stokes-Einstein equation is $D = \frac{RT}{N} \cdot \frac{1}{6\pi\eta r}$. Therefore, for a given ionic species (constant r) at constant temperature, D is proportional to $\frac{1}{\eta}$. An alternative form of Elmore's equation is therefore, for constant anode area, $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}} = k.c_m$.

The viscosities of the phosphoric acid solutions, determined on the arbitrary scale, are given in Table I and the plot of $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$ against the solubility of copper in Fig. 3. A fair straight line is obtained, demonstrating the importance of viscosity variation and indicating that c_m is related to the solubility of copper.

Relation between $i_o t_o^{\frac{1}{2}}$ and Solubility of Copper in Solutions of Constant Viscosity

If η is constant, $i_o t_o^{\frac{1}{2}}$ should be proportional to c_m.

In equalizing viscosities by the addition of glycerol, the assumption is made that the glycerol will not adversely affect the copper ion itself nor tend to be preferentially adsorbed on the anode surface. The solubility of copper is reduced by such additions and it was necessary to redetermine solubility in the modified solutions. The results are given in Table II for three solutions; the viscosities of the 50 per cent and 25 per cent solutions were adjusted to equal that of the 75 per cent solution.

Fig. 4 shows $i_o t_o^{\frac{1}{2}}$ plotted against the solubility of copper. The slope of the line is almost as expected, but the range of solubility is too restricted for the results to be convincing. In solutions of lower concentration than 25 per cent, however, it was not possible to measure t_o accurately since current and voltage changes were not sufficiently sharp.

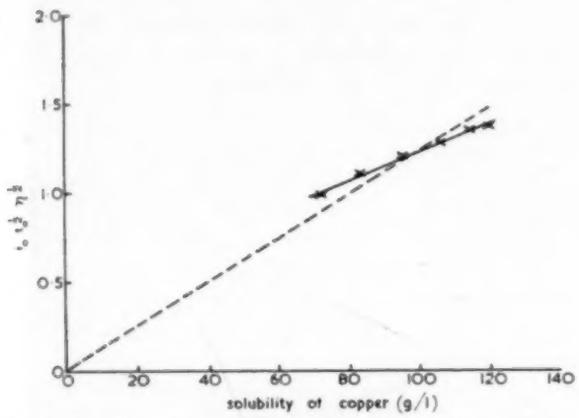

FIG. 3. Relation between $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$ and solubility of copper

Dependence of $i_o t_o^{\frac{1}{2}}$ on Concentration of Cu^{++}

The relationship between c_m and the solubility of Cu^{++} can be investigated directly by determining $i_o t_o^{\frac{1}{2}}$ for cells containing known concentrations of Cu^{++}. Elmore suggests that t_o is the time necessary for the concentration to build up near the anode to the solubility limit. If, therefore, Cu^{++} is present in the original solution, $i_o t_o^{\frac{1}{2}}$ should be less and should, in fact, be zero if the solution contains Cu^{++} up to the solubility limit.

Preliminary experiments with phosphoric acid solutions containing Cu^{++} (dissolved as the phosphate) at concentrations up to and exceeding the normal solubility showed that $i_o t_o^{\frac{1}{2}}$ decreased with increasing Cu^{++} concentration. The effect was comparatively slight, however, and it seemed likely that it was caused solely by the increase in viscosity which accompanied the increase in copper concentration. The fact that $i_o t_o^{\frac{1}{2}}$ did not reach zero even in solutions which were highly supersaturated showed conclusively that c_m is not the normal bulk solubility. To test the importance of viscosity changes, the viscosity of a solution of 100 grams $Cu_3(PO_4)_2 \cdot 3H_2O$ in 1 liter of 50 per cent H_3PO_4 was adjusted to that adopted as the standard in Table II, i.e., viscosity of 75 per cent phosphoric acid in water. With this solution, two separate determinations of $i_o t_o^{\frac{1}{2}}$ gave the results 0.096 and 0.102. The mean value is now seen to be very near that of solutions of the same viscosity containing no Cu^{++}. Thus:

	$i_o t_o^{\frac{1}{2}}$
(*a*) 75% acid	0.096
(*b*) 50% acid adjusted to viscosity of (*a*)	0.096
(*c*) 50% acid and 100 g/l phosphate adjusted to viscosity of (*b*)	0.099

The effect of Cu^{++} additions, therefore, appears to be confined to their influence upon viscosity, i.e., c_m bears no relation to Cu^{++} concentration.

This result was checked on solutions containing copper dissolved anodically and no added glycerol, correcting for viscosity differences by calculating the values of $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$. These values should be independent of Cu^{++} concentration if

TABLE II. *$i_o t_o^{\frac{1}{2}}$ and solubility of copper in solutions of constant η*

Phosphoric acid % by vol	Solubility of Cu^{++} g/l	$i_o t_o^{\frac{1}{2}}$ amp $sec^{\frac{1}{2}}$
75	81	0.096
50(+glycerol)	82	0.096
25(+glycerol)	49	0.067

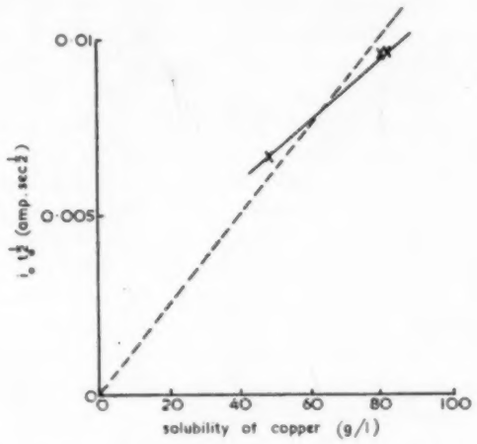

FIG. 4. Relation between $i_o t_o^{\frac{1}{2}}$ and solubility of copper in solution of constant viscosity.

TABLE III. *Dependence of $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$ on concentration of Cu^{++}*

Cu^{++} conc, g/l	$i_o t_o^{\frac{1}{2}}$ amp $sec^{\frac{1}{2}}$	η sec/20 ml	$i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$
0	0.174	54.9	1.29
5	0.168	57.9	1.28
10	0.164	61.7	1.29
15	0.159	65.9	1.29
20	0.154	70.8	1.29
25	0.151	76.0	1.32
30	0.146	80.5	1.31
35	0.142	85.1	1.31
40	0.136	89.4	1.29
45	0.132	94.6	1.28
50	0.129	98.6	1.28
55	0.124	103	1.26
60	0.120	109	1.25
65	0.117	113	1.24
70	0.114	119	1.25
75	0.108	128	1.22
80	0.102	133	1.18
85	0.100	142	1.19

the conclusion reached above is correct. The results are listed in Table III for 50 per cent phosphoric acid solutions containing between 85 and 5 g/l of Cu^{++}.

The constancy of $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$ is good, confirming that the establishment of polishing does not depend upon the attainment of a critical concentration of Cu^{++} at the anode surface.

Further evidence that copper dissolution is not controlled by the Cu^{++} concentration was obtained by electropolishing a copper anode in 50 per cent phosphoric acid, the anode and

cathode being separated by a porous pot. The Cu^{++} concentration built up to a value far greater than the normal solubility, but polishing still continued. Even when considerable crystallization of salt had occurred on the anode, it was still brightly polished at the edges and between the crystals on the faces.

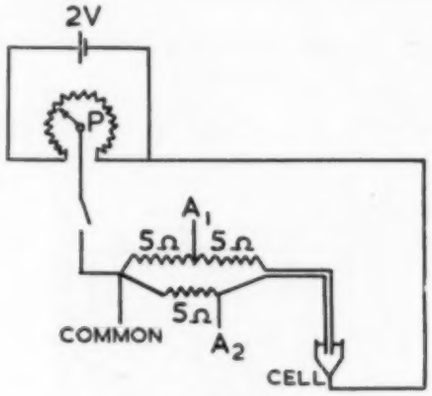

FIG. 5. Circuit (A)

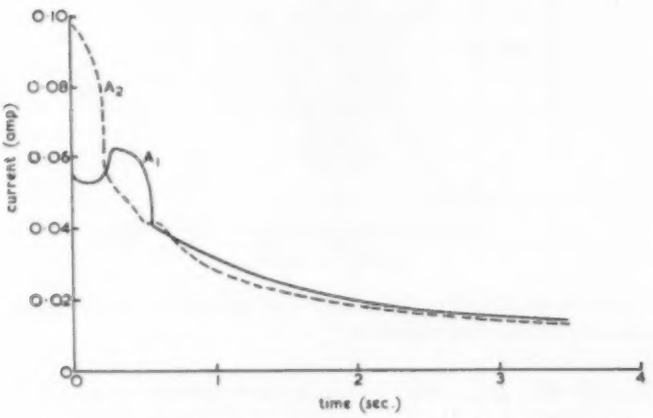

FIG. 6. Current-time curves on laminated anodes (A)

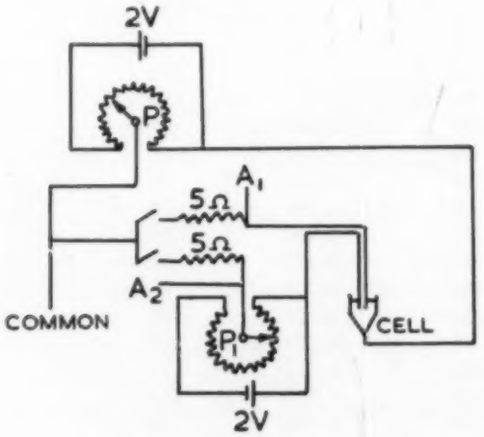

FIG. 7. Circuit (B)

Current Distribution over a Surface of Non-Uniform Potential under Polishing Conditions

It is suggested in the discussion below that the effect of slight potential variations over the anode surface is suppressed on attaining polishing conditions. This has been tested by means of a laminated anode used in the smoothing studies reported in Part II. The details of construction are described in that paper. The anode consisted of a stack of leaves of copper foil glued together with intervening leaves of mica and having alternate copper leaves connected together. The anode face was flat so that the two sets of leaves were level. In the two experiments described below, different means were chosen for maintaining a small potential difference between the two sets of leaves.

Potential Difference by Additional Resistance in One Lead

The circuit is shown in Fig. 5. The cell contained the laminated anode and 150 ml of 50 per cent by volume phosphoric acid. The potential difference between the two leads is variable but can be readily calculated from the current flowing through them. It becomes zero only when the current through the A_2 lead is twice that through the A_1. Current-time curves were photographed directly on a double beam oscillograph. The curves reproduced in Fig. 6 were obtained when a total of 1.8 volts was applied to the potentiometer P. Calculation shows the potential difference to be approximately 0.1 volt both at the beginning and end of the traces, although it rises well above that value in between. Within the accuracy of the oscillograph amplifiers, the current through both leads is the same after the final fall in current which indicates the establishment of polishing conditions.

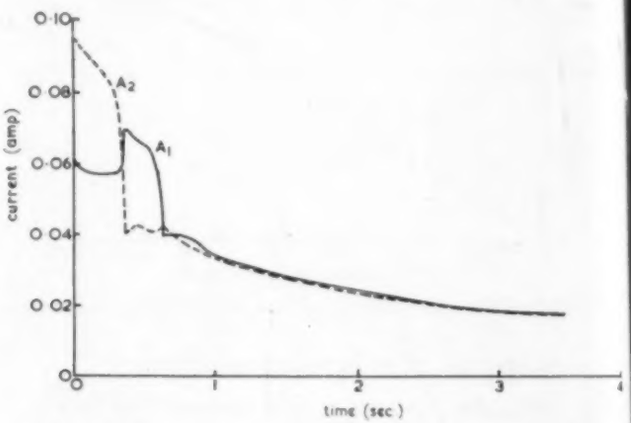

FIG. 8. Current-time curves on laminated anodes (B)

Potential Difference by Auxiliary Supply

The circuit is shown in Fig. 7. The cell was the same as before. The double-pole switch was included to prevent a current flowing between the two sets of leaves before the application of the voltage across the cell. P_1 was a low resistance (1Ω) potentiometer so adjusted as to give a potential difference between the two leads of 0.2 volt (on open circuit). The curves reproduced in Fig. 8 were obtained when 1.8 volts was applied to the A_2 lead and 1.6 volts to the A_1. Once again the current flowing through the two sets of leaves is seen to become the same when polishing conditions are established.

Discussion

The influence of changes in viscosity and the fact that the length of the transition period before polishing begins is approximately inversely proportional to the square of the current density indicate that diffusion is the controlling factor in electropolishing and that the attainment of a critical concentration at the anode surface of some constituent of the solution is responsible for the onset of polishing. However, it is clear from the experiments described above that Elmore's hypothesis is incorrect in attributing this effect to dissolved copper.

An equation similar to Elmore's was derived first by Sand

(2) to express the time necessary to reduce the concentration of ions discharging at an electrode surface to zero in an unstirred solution. This equation was verified for certain cathodic processes under conditions such that convection was small (3). Even where great care was not taken to avoid convection, the relation was found to apply fairly well for currents appreciably higher than the limiting value in the oxidation of ferrous and the reduction of ferric ions (4). By analogy with these cases a tentative explanation of electropolishing is developed below based upon the view that the controlling process is the depletion of the anode layer with respect to "acceptors," i.e., those ions or molecules with which the metal ions are combined in solution.

In many electropolishing electrolytes, the metal dissolves as a complex ion and, in these cases at least, the concept of acceptors (which could be anions or even water molecules, for instance) is plausible. Another explanation of the results reported in this paper is possible, however, in terms of hydrogen ions. These are removed from the anode layer not by discharge or combination but by migration toward the cathode. An equation of the same form as Elmore's would express the time necessary to reduce their concentration at the surface to a critical low value at which the metal ions would be insoluble and a hydroxide or basic salt might be formed; this could be the point at which polishing conditions are established. The acceptor hypothesis is preferred, however, since it is simpler on this basis to account for the principal characteristics of electropolishing. If further experimental work established the importance of hydrogen ion migration, much of the acceptor mechanism should still hold with only minor modification.

Acceptor Hypothesis

Since copper phosphate is insoluble in water but soluble in phosphoric acid, it seems reasonable to assume that the acceptors present in the copper-phosphoric acid cell are phosphate ions of some sort. It is postulated that upon the application of a voltage, these ions are used up by combination with Cu^{++} at a rate determined by the current and the number of such ions per Cu^{++} in the copper complex, their concentration at the anode thereby decreasing. If the current is low, a steady state diffusion layer may be set up such that the rate of supply of acceptors is able to balance their rate of combination with cupric ions. At higher currents, however, the concentration at the anode will ultimately reach zero. After this point the rate of dissolution of copper will be determined solely by the rate at which the phosphate ions arrive at the anode. The current can therefore no longer be maintained by the dissolution of copper alone, and the anode potential will consequently increase and the current fall. If the anode potential reaches that required for oxygen evolution, this process will intervene and the remaining voltage be taken up in the ohmic resistance of the cell once more, the discharge of hydroxyl ions permitting the additional current to pass. If this potential is not reached, the current will be established at a value corresponding to the rate of arrival of acceptors, and variation of the voltage within this range will not alter the current, i.e., the current-voltage curve will have a horizontal portion, typical of electropolishing cells of this kind. This is because the acceptors, being large ions or neutral molecules in the presence of small fast-moving cations which carry most of the current, are brought up to the anode by diffusion and convection but not, to any great extent, by electrolytic migration.

The attainment of zero concentration of phosphate ions at the anode would be expressed by a modified version of Elmore's equation in which the solubility limit of copper is replaced by the effective concentration of phosphate ions in the bulk of the solution. It was seen in Fig. 2 and 3 that, when allowance is made for varying viscosity, $i_o t_o^{\frac{1}{2}}$ is approximately proportional to the solubility of copper in the solution.

If the fairly reasonable assumption is made that the solubility of copper is determined by the concentration of phosphate ions over a range in which the concentration of Cu^{++} is small compared with that of phosphoric acid, then the conclusion reached above is confirmed. This argument is weakened by the admitted unreliability of the copper solubility values which were not accurately reproducible and by the fact that, due to the well-known complexities of phosphoric acid and phosphate solutions, it has not been possible to produce any direct experimental evidence of a relationship between copper solubility and phosphate ion concentration. The results in Table I, showing a maximum for both $i_o t_o^{\frac{1}{2}} \eta^{\frac{1}{2}}$ and for copper solubility at a phosphoric acid concentration of 40 per cent by volume, may indicate that the acceptors are hydrated ions, so that their concentration falls off at high acid concentrations at which there are fewer water molecules, as well as at low acid concentrations at which are fewer ions.

This hypothesis seems to explain adequately why there should be a sharp change in electrical conditions without the separation of a new phase. At the end of the transition period the layer of electrolyte immediately in contact with the anode does contain a limiting concentration of dissolved copper but only because there are no more phosphate ions at that instant to dissolve more and not in any absolute sense, as appeared from Elmore's hypothesis. Thus, after this point, the copper concentration will probably increase, since the diffusion away of the complex ions is likely to be slower than the arrival of new phosphate ions, on account of the larger size of the former. Since the controlling factor is the diffusion of phosphate ions and not of dissolved copper, it can be seen why it is possible to polish even in a saturated solution in which the concentration gradient of dissolved copper must be very nearly zero, and why $i_o t_o^{\frac{1}{2}}$ is practically independent of copper concentration in solutions of constant viscosity.

Elmore supposed smoothing to be accounted for by the differences in concentration gradient adjacent to high and low points on the surface. The alternative view given above (as to which is the controlling diffusion process) would still permit this mechanism to operate. However, full discussion of this point is deferred to Part II of this paper in which the results of quantitative experiments on smoothing action are reported.

The other characteristic feature of electropolishing, viz., the suppression of crystallographic etching, may be accounted for on the basis of the acceptor mechanism. Since the acceptors in the electrolyte arrive at the anode surface under the influence of diffusion and possibly convection but not, to any great extent, of electrolytic migration, their distribution over the surface will be unaffected by slight potential differences due to crystal structure, i.e., their distribution will be random. Now, if, as postulated, the concentration of acceptors at the surface after the transition period is zero, then every acceptor which arrives at the surface must be regarded as immediately removing that copper atom with which it comes in contact. Consequently, dissolution will be independent of crystal structure and no etching will result. However, in the condition before polishing is established there will be an excess of acceptors on the surface so that the relative rates of dissolution at different points on the surface will be determined by the potential energies of the copper

atoms at those points. Dissolution will be influenced, therefore, by crystal structure, and etching will be expected.

Piontelli's (5) explanation of this feature was rather similar to the above, but he appeared to claim that low acceptor concentration at the anode would be sufficient to prevent etching, whereas the suggestion now made is that the concentration must actually reach zero. Hoar and Mowat (6) suggested that the random distribution of vacant lattice sites in a solid film on the anode surface could insure the suppression of etching, but this explanation takes no account of the presumed tendency of metal atoms with higher potential energies (due to crystal structure) to pass preferentially into the lattice. However, the existence of an oxide film on an anode surface, which did not prevent the continued dissolution of the metal, might well be accompanied by polishing, since the formation of the film would be expected to depend upon the prior attainment of zero concentration of acceptors at the surface (with consequent shift of potential to that required for hydroxyl ion discharge).

It has already been mentioned that since the current under polishing conditions depends solely on the rate of arrival of acceptors at the surface, it is independent of the applied voltage within this range. The above explanation of the suppression of etching is an extension of this principle, i.e., the rate of dissolution from various areas on the same surface is likewise independent of potential differences existing between them. This fact has been confirmed by the experiments described above, using a composite anode with externally applied potential differences.

The tentative hypothesis given above has been developed with particular reference to the copper-phosphoric acid cell, but it is felt that similar considerations could apply to all electropolishing (and chemical polishing) systems. The main differences would lie in the existence of simultaneous secondary processes (gas evolution, film formation, etc.) incidental to the controlling process, although in some cases perhaps helping to maintain it. In chemical polishing, the substitution of electron-accepting anions for an external voltage need not modify the essential mechanism of polishing.

Acknowledgment

The author wishes to record his thanks to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish the account of this work. Grateful acknowledgment is also made to Dr. G. L. J. Bailey and Mr. E. A. Ollard for many helpful discussions.

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Current Affairs

Wrightsville Beach Offers Many Attractions for Fall Meeting

The fall meeting of The Electrochemical Society will be held at Wrightsville Beach, near Wilmington, North Carolina, from September 13 through 16. This will be the 104th meeting of the Society. The location is ideal for a convention as it offers all the charm of a resort but is small and intimate enough to permit members to meet easily for either social or scientific visits.

Harbor Island, the home of International Nickel Company's Marine Laboratory and Testing Station, is but two city blocks from famous Wrightsville Beach, and is connected with a modern causeway bridge. Located ten miles east of the historic city of Wilmington, and primarily a residential ocean resort on U. S. Highways 74–76, Wrightsville offers many attractions including the charm of the vast Atlantic Ocean and the cordial welcome that is always extended. There is an excellent white sandy beach where surf bathing is very popular. For those who wish to swim, Wrightsville Sound is perfect. Wrightsville Beach has a superb climate, with an average temperature during September of 75°.

This island beach is self-contained with its own stores, hotels, cottages, churches, movie theater, club, and many other attractions. The sound, the surf, and off-shore fishing is most popular for channel bass, sail fish, bluefish, mackerel, and other game fish. Chartered boats are availalbe.

Headquarters

The Ocean Terrace Hotel at Wrightsville Beach will serve as convention headquarters where registration, social functions, and most of the technical sessions will be held. As usual, reservations of hotel accommodations at an early date is strongly recommended. These should be mailed direct to The South Eastern North Carolina Beach Association, P. O. Box 698, Wilmington, N. C., attention Mr. Jack Farrell.

Chairmen

F. L. LaQue of International Nickel Company is General Chairman of the meeting and F. A. Lowenheim is Chairman of the Finance Committee. The local staff of International Nickel Company at Wrightsville Beach will take charge of the details for all meeting arrangements. Committee members are R. B. Teel, *Hotel* and *Plant Visits Committees*; W. G. Dawson, *Registration* and *Local Transportation Committees*; H. T. Paterson, *Entertainment Committee*.

F. L. LaQue
General Chairman

Technical Sessions

The Society will hold technical sessions from Monday, September 13, through Wednesday, September 16. In addition, the annual meeting of the Sea Horse Institute will be held during the same week, September 16 to 18.

The Corrosion Division of the Society has planned two special symposia: (1) Marine Corrosion, and (2) Titanium Corrosion. Also, corrosion papers of general interest will be presented. Corrosion sessions will be held on Wednesday, September 16, which will coincide with the first day of the annual meeting of the Sea Horse Institute.

The Electrodeposition Division is arranging several sessions dealing with general electrodeposition problems.

The Battery Division plans two round-table discussions on the following topics:

1. "Low Temperature Performance of Primary Batteries"—with J. J. Coleman of Burgess Battery Company as moderator.

2. "Corrosion of Positive Grids in Lead-Acid Storage Batteries"—with J. C. White, Naval Research Laboratory, as moderator.

There will be no formal papers

Air view of International Nickel Company's Marine Corrosion Testing Station located at Harbor Island.

presented by the Battery Division at this meeting.

The Electrothermic Division tentatively plans a round-table discussion.

Plant Trips

Arrangements are being made for an organized inspection of The International Nickel Company's corrosion testing station at Harbor Island, and also their atmospheric testing stations at Kure Beach, some twenty miles away. Buses will be provided for transportation to the latter.

Social Functions and Ladies' Program

A novel feature of the social functions that has been arranged is a barbeque dinner scheduled for Monday evening, September 13. The reception and banquet will take place on Tuesday evening, the highlight of which will be the awarding of the Palladium Medal (The Palladium Medal address will be given earlier in the afternoon). A general Society luncheon has been arranged for Wednesday noon, September 16. Some of the divisions are planning luncheons which will be announced.

Seventh Annual Battery Research and Development Conference

The Battery Division of The Electrochemical Society was prominently represented at the Seventh Annual Battery Research and Development Conference sponsored by the Power Sources Branch, Signal Corps Engineering Laboratories, Fort Monmouth, New Jersey. The meeting was held at the Berkeley-Carteret Hotel in Asbury Park on May 13 and 14. It was of especial interest to the Battery Division of the Society, many of whose members took part in the discussions and presented papers.

These conferences are held annually under the direction of Grenville B. Ellis, assisted by David Linden, for the purpose of presenting the results of Government sponsored battery research and development, and to provide a means for the exchange of technical information between the Government agencies and the battery industry. Over 150 commercial and Government groups, represented by almost 400 individuals, attended.

The 2-day meeting consisted of three symposia covering battery research, dry cell batteries, and special purpose batteries.

Battery Research

Under this head was "Aluminum Cell Systems," discussed by A. B. Garrett, Ohio State University; "Improved Storageability," on which investigations were reported by Olin Industries; "Dry Cell Capacity Predictor," which was the subject of a discussion by Grenville B. Ellis of SCEL; and "Solid Ion Conductor Batteries," in which W. Van der Grinten of General Electric Company described investigations being done by his company and SCEL.

Special Purpose Batteries

The symposium on special purpose batteries featured a round-table discussion on the zinc-silver oxide electrochemical system. Taking part was John B. Conn of Merck & Company, who proposed a reaction mechanism for the zinc-silver oxide battery in which silver (II) oxide functions as a reservoir of silver (I) oxide, furnishing capacity without contributing to the potential of the cell.

SCEL and the Eagle-Picher Company reported that the interim standard line of "A" and "B" zinc-silver oxide batteries has been completed and is now available on an off-the-shelf basis for supplying the power required by the various equipment designers of rockets, missiles, and other special applications.

Arthur Fleischer, of Nickel Cadmium Battery Corporation, reported on investigations to improve the negative plate performance of the sintered plate storage battery. The symposium was concluded with a discussion by J. A. Mas of the Vibration Research Laboratories, Inc. on the use of vibrators and dynamotors as "B" supplies in lieu of batteries.

Battery Division members of the Society attending the Seventh Annual Battery Research and Development Conference at Asbury Park were *(left to right)* J. C. White, Naval Research Laboratory; E. J. Ritchie, Eagle-Picher Company; U. B. Thomas, Bell Telephone Laboratories; E. Willihnganz, Gould National Battery Company; A. F. Daniel, Signal Corps Engineering Laboratories; C. C. Rose, Willard Storage Battery Company; and A. G. Hellfritzsch, Naval Ordnance Laboratory.

Dry Cell Batteries

This subject covered "Magnesium Batteries," in which Roy C. Kirk of the Dow Chemical Company and J. Hovendon of SCEL presented the results of the last year's efforts in the field of magnesium dry cell batteries. Investigations on "Miniature Low Drain Long Life Cell" were concerned with the improvement of the shelf life characteristics of the battery and the design of fabrication equipment which will be satisfactory for laboratory scale production.

The conference concluded with a discussion of "Manganese Dioxide and Carbon Black," two of the more important components of the dry cell battery. Edward W. Samoden of the Tennessee Corporation reported on experimental investigations on the development of methods of electrolytically synthesizing manganese dioxide to give optimum battery performance when discharged under certain specified conditions, and A. V. Peppard of Godfrey L. Cabot reported on investigations leading to the development of a domestic source of battery grade carbon black.

* * *

Papers presented at the conference, because of their restricted nature, are not available in published form.

Highlights of the Board of Directors' Meeting

(Held April 12, 1953)

The Secretary reported that the finances of the organization were satisfactory. The primary reason for the improved financial picture has been due to four causes: (1) an increase in nonmember JOURNAL subscriptions, (2) the increase in dues, (3) the large increase in the number of Sustaining Memberships (this is a direct result of Mr. Walter Prine's efforts), and (4) the increase in advertising revenue as a result of Mr. Bain's activities.

Mr. Bain gave a rather comprehensive report on his activities, and then requested help from the membership in obtaining contracts with several key companies. He feels that if these key companies can be persuaded to take contracts, the combined effect of this and the selling campaign that he is now waging will result in considerable increase in our advertising revenue.

The President proposed the following Nominating Committee:

George Heise, *Chairman*
Harold Read
Norman Hackerman
John Gall
Ralph Hunter
Harry Copson, *Alternate*

This appointment was approved.

The Treasurer reported on the Consolidated Fellowship Funds, and it was decided that a residue would be left in the National City Bank to make it possible to handle further income to this fund in a more expeditous fashion.

The possibility of publishing abstract cards was discussed. This suggestion was received from N. C. Cahoon of the Cleveland Section. No decision was made at this meeting, but it was agreed that the proposition would be studied.

The Secretary reported that to date we have 261 prepaid orders and 110 statements to the effect that the signers will purchase the Ten-Year Index when published. On the basis of this return, the Board authorized the Secretary to proceed with publication of the Ten-Year Index.

General discussion of future meetings of the Society was held. The meetings are as follows:

Fall, 1953—Wrightsville Beach, Sept. 13–16, Ocean Terrace Hotel
Spring, 1954—Chicago, May 2–6, La Salle Hotel
Fall, 1954—Boston, October 3–7, Statler Hotel
Spring, 1955—Cincinnati, May 8–12, Sheraton-Gibson Hotel
Fall, 1955—Pittsburgh, October 9–13, William Penn Hotel
Spring, 1956—San Francisco
Fall, 1956—Cleveland

The Local Section Advisory Committee reported that it is nearly ready to make formal application to the Board of Directors to change the setup of that committee. The Ways and Means Committee is cognizant of the proposed changes which will be announced formally when final decision is made.

The Young Author's Prize winner, W. E. Kuhn, The Carborundum Company, and the Francis Mills Turner Memorial Award, Sponsored by the Reinhold Publishing Corporation, winner, P. T. Gilbert, The British Non-Ferrous Metals Research Association, were announced.

The Palladium Medal Committee announced their recommendation of Professor N. H. Furman of Princeton University as Palladium Medalist. This recommendation was accepted.

President Warner outlined the current situation at the National Bureau of Standards with respect to the dismissal of Dr. Astin. He requested that Dr. Burns, Dr. Hunter, and Mr. McKay collaborate with him in preparing a proposal to bring to the Tuesday afternoon session of the Board.

At the conclusion of the business of this meeting, the Secretary announced that he had completed the first term of service on an appointed basis, and since it is his feeling that such appointment should be made for one year, and that the Board should be placed each year in a position where a change could be made readily, he formally resigned from the position of Secretary and withdrew from the proceedings. Action of the Board followed, reappointing Henry B. Linford as Secretary for the next year.

The meeting recessed at 5:15 p.m. until 4:00 p.m., Tuesday, April 14.

* * *

Resumption of Board of Directors' Meeting, April 14, 1953

The Secretary requested permission to deal expeditiously with the rental of the National Office. Since, undoubtedly, rates will be increased, he felt that it would be well to be placed in a position where he could, on advice from Dr. Burns, Mr. McKay, and others in the immediate area, move the National Office if more advantageous quarters could be found. Since this move would have to take place before July 1, it was necessary to have this enabling action.

The Nominating Committee reported as follows:

"Your Nominating Committee, on the basis of a meeting held April 13, 1953, recommends the followin geandidates for office in The Electrochemical Society:

For President:
Marvin J. Udy
For Vice-President:
Norman Hackerman
John R. Musgrave
Fred A. Lowenheim

"Each of these men has verbally signified his willingness to stand for office and to serve if elected.

Respectfully submitted,
(Signed) H. R. COPSON
J. F. GALL
R. M. HUNTER
H. J. READ
G. W. HEISE, *Chairman*"

On the motion of Dr. Hunter, it was voted that the Board accept the report of the Nominating Committee.

President Warner then brought up the matter of a formal protest prepared since the Sunday Board meeting regarding the Astin dismissal. It was then agreed that the protest, as published in the June issue of the JOURNAL, be sent to the following people:

1. Sinclair Weeks, Secretary of Commerce
2. Dr. Allen V. Astin
3. Senate Small Business Committee
4. President Eisenhower
5. George Vinal
6. Walter Hamer
7. Paul Howard
8. Senate Committee on Commerce and Industry

The remainder of the time was spent with Mr. Bain, going over 41 companies in which he requested help in approaching the advertising managers. Members were assigned to make the contacts for Mr. Bain and to work with him in these particular companies.

The meeting adjourned at 5:15 p.m.

HENRY B. LINFORD, *Secretary*

Correction

In the article by J. O'M. Bockris which appeared in the December 1952 JOURNAL, pp. 366*C* and 367*C*, in equations (IV), (V), (VI), (VII), (X), (XI), and (XII), "exp" should be substituted for "e."

Atomic Industrial Forum Being Organized

Incorporation papers for an organization of businessmen, engineers, scientists, and educators interested in the industrial development and application of atomic energy for peaceful uses have been filed with the Secretary of State in Albany.

Presidents or key atomic energy executives of 13 corporations and institutions of higher education were named as directors of the group, which will be known as the Atomic Industrial Forum, Inc. The Forum will have its present headquarters in the Engineering Societies Building, 29 West 39th Street, in New York.

A broad membership of all businessmen, engineers, scientists, educators, and others involved or interested in atomic energy as a new and promising industry will be sought by the Forum, it was stated by its founders. There will be two classes of membership. Regular memberships will be open to individuals who are lawfully entitled to access to any "restricted data" as defined in the Atomic Energy Act of 1946. Special membership will be open to individuals, corporations, associations, partnerships and trusts which are now or expect to be engaged in research, development, or operations in atomic energy. Regular members only will have voting privileges and be eligible to serve on the Forum's board of directors.

Dr. T. Keith Glennan, president of Case Institute of Technology, in proposing an association, declared it "should provide a forum in which industry might develop its best thinking in the interest of the advancement of the peacetime uses of atomic energy; a forum in which industry might develop an informed voice to be heard at governmental levels as new atomic energy policy is hammered out; a forum, not to serve the narrow interests of a few, but to stimulate the industrial development of atomic energy for the good of all."

Later in his speech Dr. Glennan declared "there is no question but that the enlightened self-interest of competitive enterprise in the course of atomic energy development is also the public interest, and I don't think I am alone in this belief. For evidence of this, I need only point to the atomic energy law of this country, which declares that one of the principal objectives of the atomic energy program is the stimulation of free competition in private enterprise."

AIC Gold Medal Presented to J. C. Warner

The Gold Medal, highest award of the American Institute of Chemists, was presented in May to J. C. Warner, president of Carnegie Institute of Technology, and 1952–53 president of The Electrochemical Society. The presentation took place at the Benjamin Franklin Hotel in Philadelphia.

Dr. Warner has made outstanding contributions to science in the fields of corrosion of metals, the carbonization of austenite, the heats of mixing of

J. C. WARNER

nonelectrolytic solutions, the kinetics of ionic reactions, and the acid-base properties of mixed solvents. He is the author of more than 50 technical articles and is coauthor of a number of important chemical texts. During World War II, Dr. Warner headed government research on the purification and metallurgy of plutonium for the Manhattan Project. He is currently a member of the Atomic Energy Commission's General Advisory Committee, appointed for a 6-year term.

Acheson Nominations Due Sept. 1, 1953

Ernest G. Enck, Chairman of the Acheson Medal Award Committee, desires to receive suggestions for possible candidates for the next Acheson Medal Award, to be made in the fall of 1954.

Chairman Enck announces that the date for receiving these nominations has been moved forward (with the approval of the Board of Directors) to *September 1, 1953*. All nominations should be in his possession on or before that date.

The procedure to be followed by the membership in naming candidates was published in the March issue of the JOURNAL, page 68C.

Electrochemistry Course in Cleveland Area

A survey course in applied electrochemistry is offered by Western Reserve University during the first term of the summer session, June 22–August Topics to be covered will include electrometallurgy, the electroprocess industries, various aspects of plating and electrodeposition, electropolishing, battery technology, and corrosion. Conducting the course will be Dr. Allen Gray, technical editor of *Steel* magazine and ditor-in-chief of The Electrochemical Society's forthcoming book *Modern Electroplating*.

DIVISION NEWS

Electrothermic Division

Following the Division luncheon at the Hotel Statler in New York City on Tuesday, April 14, 1953, the annual business meeting was held.

C. H. Chappell, Chairman of the Division, called the meeting to order and requested that the secretary-treasurer's report be presented. Accordingly, I. E. Campbell presented his report as follows:

The net income for the past fiscal year was $64.00, thus increasing the net worth of the Division to $3427.8 Statistics were presented pertaining to the membership of the Division, which after a net gain of 12 for the past year represented a total of 265.

Dr. Campbell also spoke of the proposed amalgamation of the Rare Metals group of the Electronics Division with the Electrothermic Division. Although no formal action was taken, the members of the Division expressed their approval of the proposal.

A brief report was made of progress pertaining to the Monograph on "High Temperature Material, Methods and Measurements." The first draft should be completed within two or three months.

After expressing thanks to J. S. Dewar for his efforts in organizing the meetings just concluded, Dr. Chappell read the report of the nominating committee. The committee, composed of A. T. Hinckley, Chairman, H. C. Oswald, and J. H. Brennan, made the following nominations:

Chairman—I. E. Campbell
Vice-Chairman—J. S. Dewar
Secretary-Treasurer—A. C. Haskell, Jr.
Members-at-Large on the Executive

Committee—J. W. Glasser and M. H. Udy

As no further nominations were made from the floor, a resolution was adopted to authorize the Secretary to cast a unanimous ballot for all of the nominees. Dr. Campbell then opened a brief discussion pertaining to the next Fall and Spring Meetings. A few subjects were proposed and appropriate committees will be selected. Additional suggestions should be sent to the Secretary-Treasurer.

A. C. HASKELL, JR., *Secretary-Treasurer*

Theoretical Electrochemistry

A business meeting of the Theoretical Electrochemistry Division was held at the New York Convention on Thursday, April 16, 1953, with H. R. Copson presiding as acting chairman. The chief item of business was the election of new officers. There were several nominations from the floor, and a vote resulted in the election of the following to serve for two years:

Chairman—J. P. Fugassi

Vice-Chairman—E. B. Yeager

Secretary-Treasurer—P. Delahay

There was then some discussion of the possibility of publication, prior to the convention, of some form of preprints of the papers on the program. The new officers of the division were requested to look into the possibility of an extended abstracts booklet, modeled after the one printed by the Electronics Division.

W. J. HAMER, *Chairman* (1952)

SECTION NEWS

Detroit Section

A dinner meeting, featured as "Students' Night," was held by the Detroit Section on April 24 in honor of Professor A. L. Ferguson of the University of Michigan and Professor D. T. Ewing of Michigan State College. The meeting took place at Wayne University Student Center.

The speakers who participated at this occasion are listed below, with their subjects:

Walter Dow, Graduate Student and Research Associate, Michigan State College, "Effect of Iron Impurities in Nickel Plating Solutions and Their Removal"

Joseph Tobin, Graduate Student and Research Fellow, Michigan State College, "Porosity of Electrolytic Nickel Deposits"

John Hoekstra, Graduate Student and Research Associate, Wayne University, "Some Studies in the Mechanism in Bright Plating"

J. M. Markowitz, University of Michigan, "Electrochemical Reduction of Halogenated Compounds."

G. V. KINGSLEY, *Secretary-Treasurer*

Midland Section

J. C. Warner, Society president, was the featured speaker at the April 2 meeting of the Midland Section. Ralph M. Hunter, past president, made some introductory remarks sketching the busy life of Dr. Warner.

Dr. Warner spoke on the subject of "Histories of Theories of Electrolytes." He concisely and thoroughly discussed the history behind the development of theories of electrolytes, and the talk was well dispersed with slides. The contributions of Valson were first discussed, then the five postulates of Arrhenius. The ten proposed forms of the Dilution Law from Ostwald in 1887 to Kraus and Bray in 1914 were next shown.

After 1914, the speaker said, theory

New Address

FOR

The Electrochemical Society, Inc.

216 West 102nd Street New York 25, N. Y.

Telephones—RIverside 9-0602 and RIverside 9-0603

The Electrochemical Society has moved its offices to larger quarters, located on the southeast corner of 102nd Street and Broadway. This is diagonally across Broadway from the former location. After July 1st, all communications to the Society and the JOURNAL should be addressed to the new number, *216* West 102nd Street. Telephone numbers remain the same.

was supplanted by more intensive experimental work. The thermodynamic properties of electrolytes were studied by Lewis and Noyes and in 1923 the Debye-Hückel theory was presented. Noyes later interpreted the work of Debye and Hückel—contributing much to early acceptance of the theory. Later, the Debye-Hückel-Onsager theory, pertaining to electrostatic and electroviscous retarding forces, was discussed. A conductance equation for a 1–1 salt was developed. Several slides showed plots of functions of the Debye-Hückel theory.

Dr. Warner then led the discussion to dilute systems and stated that a conductivity theory from the modern point of view is very difficult. Poisson's equation was solved for two cases—high and low concentration. Another slide showed the effect of ionic diameter upon the activity coefficient. An anlaysis of organic acids, he said, would be very difficult. Dr. Warner completed his talk with a prediction that future theoretical interest would be in fused salts and nonaqueous systems.

Preceding the meeting, members of the Section gathered at the Midland Country Club for an informal dinner with Dr. Warner.

F. N. ALQUIST, *Secretary-Treasurer*

Philadelphia Section

The Philadelphia Section held its final meeting of the season on Saturday, May 9th. Following its custom, the Section had arranged an interesting afternoon and evening outing program to which the ladies were especially invited; approximately forty members and guests attended. The meeting was held in the Pfahler Hall of Science at Ursinus College, Collegeville, Pa.

The principal event was a most interesting and enjoyable talk, "To the Land of the Zulus," given in the evening by Ernest G. Enck, Secretary of the Foote Mineral Company and an active member of the Philadelphia Section.

In his talk, Mr. Enck related his experiences in Africa in connection with the procuring of lithium minerals and other ores for his Company's operations. Mr. Enck guided the group through the vast mysterious depth of Kruger Park and, by jeep and trekking, across the great South African veldt.

The group was impressed by the primitive character of the African mining operations. Numerous Kodachrome slides contributed to the impressions of the African scene.

In the afternoon, the group assembled at the Audubon Shrine development, Audubon, Pennsylvania, where J. D'Arcy Northwood, the curator, gave a brief talk on the Audubon lore, and also discussed the copper and lead mining operations which from time to time have been pursued on the property. The group took time to enjoy this historic site and its rural beauty and to examine the collection of Audubon color prints of birds and other natural life.

The group then went to the locally famous Lakeside Inn in Limerick for a pleasant social hour and dinner. After dinner the party proceeded to Ursinus College where a brief conducted tour of the campus had been arranged.

John F. Gall, the Philadelphia Chairman, opened the meeting with a word of appreciation to Ursinus College for kindly providing the Philadelphia Section with a very satisfactory meeting place. The Ursinus host, Professor William S. Pettit, responded with an expression of welcome.

In a short business meeting, the Philadelphia Section voted to accept in principle the proposed changes in our Society's bylaws which are intended to reorganize the Local Section Advisory Committee.

The Section then held its annual election of officers, and the following persons were elected for the 1953–1954 term:

Chairman—J. Fred Hazel
Vice-Chairman—Edgar L. Eckfeldt
Treasurer—G. Franklin Temple
Secretary—George A. Bodamer

The program proved to be very enjoyable throughout and was the highlight of the Philadelphia Section's season.

E. L. ECKFELDT, *Secretary*

New York Metropolitan Section

The final meeting of the season was held on May 13, 1953, at the Hotel Holley. This meeting was the Third Annual Ladies' Night and featured favors, door prizes, and other special attractions for the wives of the members, who turned out in good quantity (and needless to say, high quality).

The featured speaker of the evening was R. M. Bowie, Director of Engineering for Sylvania Electric Products Incorporated, who spoke in a semi-technical manner on color television. Dr. Bowie explained the principles involved in televising color and gave a short history of the various means which have been proposed to solve the problems. His talk was very well received and he was kept answering questions until a late hour.

Preceding the principal speaker, Dr. Carl Kolbe of the General Electric Company showed a short color film on the forging of molybdenum alloys in inert atmospheres.

The following officers were elected for the coming year:

Chairman—Herbert Bandes
Vice-Chairman—Martin F. Quaely
Secretary-Treasurer—Kenneth B. McCain
Members of the Executive Committee—Past-Chairman, A. C. Loonam, M. B. Diggin, C. V. King, and Fred P. Peters

F. A. LOWENHEIM, *Secretary-Treasurer*

PERSONALS

FELIX E. WORMSER, president of Lead Industries Association, New York, was recently appointed by President Eisenhower to be Assistant Secretary for Mineral Resources in the Department of the Interior, Washington, D. C.

HUBERT M. GOLDMAN has been appointed to the newly-created post of assistant to the sales manager and technical engineer at Enthone, Inc., New Haven, Conn. EDWARD F. FOLEY has been named research chemist in the company's enlarged research facilities.

CLAIRE C. BALKE, formerly Director of Research and Chief Engineer, Roberts and Mauder Corporation, Hatboro, Pa., is now president and treasurer of Balke Research Associates Inc., Doylestown, Pa.

PERCY E. LANDOLT, Lithium Corporation of America, Inc., New York City, has been elected president of the Columbia University Engineering School Alumni Association for the 1953–54 academic year.

RICHARD RIMBACH of Richard Rimbach Associates, Pittsburgh, left for Europe in June to visit a number of representatives of technical and scientific groups and instrument engineers in connection with the First International Instrument Congress and Exposition to be held in Philadelphia, September 13–24.

B. B. DEY has joined the Central Electrochemical Research Institute, Karaikudi, as Director.

J. V. PETROCELLI, Patent Button Company, Waterbury, Conn., has been appointed JOURNAL editor of the Corrosion Division of the Society, succeeding Michael A. Streicher, former Corrosion Division editor.

JAMES H. SCHULMAN has been named head of the Chemistry Branch of the Metallurgy Division of the Naval Research Laboratory, Washington, D. C. Dr. Schulman was formerly head of the Luminescent Section of the Chemistry Branch.

GEORGE A. PERLEY was recently presented with an Alumni Citation from the University of New Hampshire "in recognition of outstanding achievements and services in the field of chemistry."

S. KRISHNAMURTHI has been appointed deputy engineer, Plating Shop, Indian Telephone Industries, Ltd., Bangalore.

DANIEL C. OAKLEY of Ray-O-Vac Company, Madison, Wis., has joined the Blake Manufacturing Company, Clinton, Mass.

G. P. CONTRACTOR, Acting Director of the National Metallurgical Laboratory of India for a period of three and one-half years, relinquished his services with the Indian Council of Scientific and Industrial Research in April. Dr. Contractor has served with the Council for nearly nine years. He will leave India some time in August for Great Britain, on his way to Canada.

CHARLES F. VAUGHN

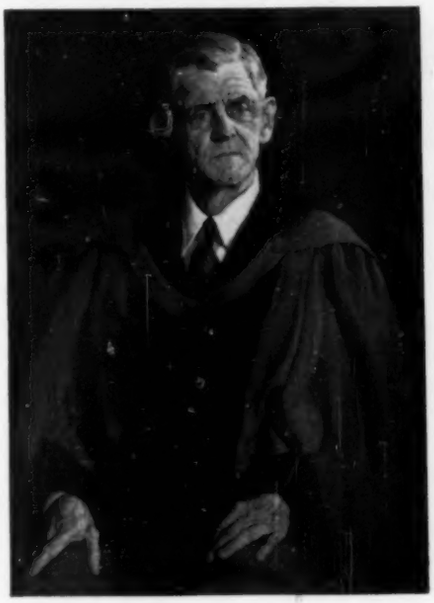
Charles F. Vaughn, retired vice-president and manager of Mathieson Chemical Corporation, died in Niagara Falls on March 30.

Charles Vaughn was born in Providence, Rhode Island, in 1874 and was graduated from Worcester Polytechnic Institute in 1896. Connected with the Mathieson Corporation for 53 years, he made many contributions to the development of batteries and perfected the Castner mercury cell. He was awarded the Schoellkopf Medal for meritorious work in the chemical field. During World War I he served with distinction as a lieutenant-colonel in the Chemical Warfare service.

Mr. Vaughn joined The Electrochemical Society in 1902, the year of its founding.

Dr. Creighton Honored at Swarthmore

A large portrait of H. Jermain Creighton, recently completed and handsomely framed, was presented to Swarthmore College by his former students and friends. A photograph of the portrait is shown below. The presentation was made on June 6 and was the occasion of many tributes to Dr. Creighton, former head of the Swarthmore chemistry department. He



Copy of portrait of Dr. H. Jermain Creighton recently presented to Swarthmore College.

retired in June 1952 after 40 years of teaching at that institution. During this time his work has made him world famous and brought him many honors.

JOURNAL readers will be interested to hear of Dr. Creighton's activities during the past year. A former Society president, he promised to travel and engage in various interesting pursuits upon retirement. Accordingly, since last June, he has visited Mexico, California, and Canada. He has threatened to leave the North American continent the next time he takes a trip.

Dr. Creighton was born in Nova Scotia and for many years he has had a summer home there, at St. Margaret's Bay. This is now his home base and he keeps a small fleet of boats there: a schooner, a motor launch, and some smaller craft—for sailing has been his lifelong recreation. In the fall, he will again follow the sun, visiting some of the warmer climates that he has not previously had the opportunity to enjoy.

NEW MEMBERS

In May 1953, the following were elected to membership in The Electrochemical Society:

Active Members

FRANCIS BITTER, Massachusetts Institute of Technology, Cambridge, Mass. (Electronics)

S. D. BOWERS, JR., U. S. Radium Corporation, mailing add: 106 West St., Bloomsburg, Pa. (Electronics)

VICENTE E. COCA, Laboratorios Quimicos Cora, mailing add: Bahia Blanca 683, Buenos Aires, Argentina (Electrothermic and Theoretical Electrochemistry)

ROLF CRANSBERG, N. V. Metallic Industry, Loosdrecht, Holland (Corrosion, Electrodeposition, Electro-Organic, Industrial Electrolytic, and Theoretical Electrochemistry)

ROBERT L. CRONE, Radio Corporation of America, mailing add: 59 E. Pine St., Ephrata, Pa. (Electronics)

ROBERT J. DAWSON, Ray-O-Vac Company, 212 E. Washington Ave., Madison, Wis. (Battery)

JOSEPH F. DONAHUE, JR., Naval Ordnance Laboratory, mailing add: 9812 Dilston Rd., Silver Spring, Md. (Battery)

PETER J. ENSIO, Quebec Iron & Titanium Corporation, mailing add: 461 Second St., St. Lambert, Quebec, Canada (Electrothermic)

JESSE J. FUCHS, U. S. Electric Mfg. Corporation, mailing add: 140-09 Jewel Ave., Kew Gardens Hills, N. Y. (Battery)

RICHARD H. GALE, Chemical Products Works, General Electric Company, 1099 Ivanhoe Rd., Cleveland, Ohio (Electronics)

ROBERT J. GOOD, Monsanto Chemical Company, Anniston, Alabama (Electric Insulation)

JOSEPH T. GUSHUE, U. S. Rubber Company, mailing add: 1230 Avenue of the Americas, New York, N. Y. (Battery and Electric Insulation)

WILLIAM H. HIGHFIELD, General Electric Company, mailing add: 295 Heath Terrace, Buffalo, N. Y. (Electronics)

JOHN W. HOOPES, JR., Columbia University, Box 102, Havemeyer, New York, N. Y. (Industrial Electrolytic)

WARREN E. HAUPIN, Aluminum Company of America, Research Laboratories, New Kensington, Pa. (Industrial Electrolytic)

ROBERT N. HAZELWOOD, Line Material

Company, mailing add: 3405 N. Hackett Ave., Milwaukee, Wis. (Electric Insulation)

SAMUEL KORMAN, Phelps Dodge Corporation, mailing add: 397 Fifth Ave., Cedarhurst, N. Y. (Electronics and Electrothermic)

ALFRED KREMHELLER, Sylvania Electric Products Inc., mailing add: 35-05 Parsons Blvd., Flushing, N. Y. (Electronics)

HERMAN A. LIEBHAFSKY, General Electric Company, mailing add: 1674 Lake Blvd., Schenectady, N. Y. (Theoretical Electrochemistry)

LEWIS G. LONGSWORTH, Rockefeller Institute, 66 St., and York Ave., New York, N. Y. (Theoretical Electrochemistry)

LEONARD MAY, National Union Radio Corporation, 350 Scotland Road, Orange, N. J. (Electronics)

ALBERT MULLER, Air Reduction Company, Murray Hill, N. J. (Electronics & Electrothermic)

WILLIAM K. MURRAY, R. Wallace & Sons Manufacturing Company, mailing add: 48 Maple Ave., Meriden, Conn. (Electrodeposition)

EDWARD S. NAIDUS, United Shoe Machinery Corporation, mailing add: 29 Cypress St., Marblehead, Mass. (Electric Insulation and Theoretical Electrochemistry)

KURT O. OTLEY, National Bureau of Standards, mailing add: 3435 Yuma St., N.W., Washington, D. C. (Electric Insulation, Electronics, and Theoretical Electrochemistry)

MAURICE H. PICKARD, Pacific Coast Borax Company, mailing add: 100 Park Ave., New York, N. Y.

HOWARD H. ROGERS, Research Division, Allis-Chalmers Corporation, Milwaukee, Wis. (Theoretical Electrochemistry)

KEITH L. SMITH, General Electric Company, mailing add: 4887 Anderson Rd., Cleveland, Ohio (Electronics)

LUKE THORINGTON, Westinghouse Electric Corporation, Research Department, Bloomfield, N. J. (Electronics)

ROBERT L. WESTLAKE, JR., National Carbon Company, Rm. 303, 292 Madison Ave., New York N. Y.

Associate Members

JOHN BETLEY, Sunray Electric, Inc., 1401 Lexington Ave., Warren, Pa. (Electronics)

EDWARD A. KURE, Willard Storage Battery Company, mailing add: 1276 E. 172, Cleveland, Ohio (Battery and Theoretical Electrochemistry)

LETTER TO THE EDITOR

More About New Nickel-Plating Process

Dear Sir:

This concerns the recently announced "Kanigen" process of the General American Transportation Corporation for depositing nickel, as described on page 127C of the May issue of the JOURNAL. It may not be out of order to point out that the deposition of nickel by reduction of nickel salts with hypophosphites is a development of Dr. Abner Brenner and his group at the National Bureau of Standards, and it is their process upon which the General American Transportation Corporation process is based. The Bureau deserves credit in this instance over and above any of the several companies who are currently commercially developing and applying the original disclosure.

In addition to the fact that the initial fundamental work was well done and merits recognition, it is also appropriate, at this critical time for the Bureau, to bring attention to another of the Bureau's many outstandingac complishments of the past fifty or more years to American industry and to American life.

H. H. UHLIG
Massachusetts Institute of Technology,
Cambridge, Massachusetts

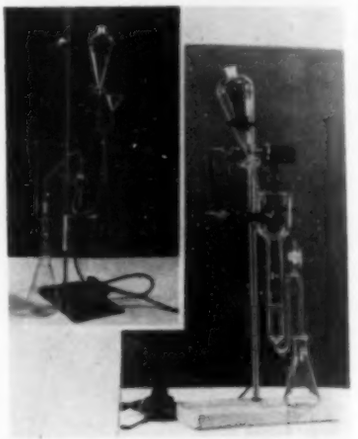
NEW PRODUCTS

VOLT - OHM - MILLIAMMETER. New Model 262 Volt-Ohm-Milliammeter features 20,000 ohms per volt sensitivity. Very compact unit housed in a 7-inch

case. Each of its 33 ranges has been customized to meet the needs of the electronic and electrical industries. Simpson Electric Co. N-13

FIBERGLAS PLATING TANK. New seamless Fiberglas tank for use with all solutions generally used in plating except caustic cleaner and hydrofluoric acid. Temperatures of tank contents may be as high as 220°F. Costs from 5 to 29% less than lined steel tanks and is equally impervious to chemical attack. Furnished in any size required. Hanson-Van Winkle-Munning Co. N-14

LIQUID-LIQUID EXTRACTORS. New type of glass apparatus, known as the Schmall Apparatus, for the extraction and determination of salts of organic bases and acids. This procedure eliminates many hand operations and facili-



tates sample preparation; also, extraction is automatic, washings are eliminated, and labor cost of analysis is reduced. Two types available: for solvents lighter than water and for those heavier than water. Scientific Glass Apparatus Co., Inc. N-15

VACUUM RHODIUM COATING SERVICE. A service, equipped to apply coatings of rhodium to nonconductive and conductive materials by using the vacuum technique, has been announced. It is applied on a commercial basis upon glass and other nonconductive substances to meet specifications of transmittancy and hardness. Rhodium has high resistance to chemical attack and is excellent for mirrors and reflecting surfaces when exposed to corrosive chemical atmospheres. Other metals that can be vacuum deposited, such as aluminum, gold, and silver, will also be applied. The coating service is available to technical laboratories, industrial organizations, etc.; the work is done on a job basis. Serfass Corp. N-16

ALUMINUM PROTECTION. New protective coating chemical for aluminum, "Alodine" No. 1200, has been developed and its effectiveness tested in 500 hours

(Continued on page 205C)

Annual Report of the Board of Directors for 1952

During the year 1952, four meetings of the Board of Directors were held. Full details of the business transacted at these meetings are contained in the minutes, on file in the Secretary's Office, where they may be consulted by any member of the Society. Only the important items of business transacted during the year of 1952 are detailed here.

The Reinhold Publishing Corporation, during the year 1952, announced their desire to continue the work of one of their officers, the late Francis M. Turner, in recognizing young authors. For many years Mr. Turner has personally offered a prize to young authors publishing in the official organ of the Society. The new award, known as "The Francis Mills Turner Memorial Award, Sponsored by the Reinhold Publishing Corporation," consists of a prize of $100 worth of books from any publisher.

Your Board, this year, has established a Consolidated Fellowship Fund from the accumulated earnings of the Weston Fellowship Fund, the Roeber Research Fund, the excess earnings of the Acheson Fund, and $1,000 returned by Dr. Marden (his Acheson Award) at the time of the Montreal Meeting. (Due to the deterioration of the Weston Fellowship funds, the control of such funds was not in the hands of the Board of Directors.) It is the policy of the Board that this fund will be accumulated until such time as the Society has available sufficient yearly income from this source to justify offering a first class fellowship, at which time we again will be in a position to sponsor graduate studies in electrochemistry.

During this past year, the following awards were made:

The Acheson Award—J. W. Marden of Westinghouse Electric Corporation.

Honorary Membership—William Blum of the National Bureau of Standards, Washington, D. C.

Young Author's Prize—John T. Byrne of The Dow Chemical Company.

Turner Book Prize—Kurt H. Stern of Clark University and Charles C. Templeton, Shell Oil Company.

Prize Essay Contest—First prize — Gordon Gemmell, Cambridge, Massachusetts; second prize — Donald W. Hutchings, Oberlin, Ohio; honorable mention — Robert Auerbach, New York City.

During the year, the Board of Directors decided to change their Sustaining Membership policy, making it possible for companies to take out more than a single membership. This campaign was started in December 1952, and to date has resulted in a total of 13 multiple memberships.

The dues schedule for the members was changed so that at present our active membership dues amount to $15, associate membership $9.50, and student associate membership $3. Subscriptions to the JOURNAL will be $15.

Several changes in operation of the Society were made: Mr. Frank LaQue resigned as Business Manager of the JOURNAL for reasons of health. Since his retirement date, the duties of the Business Manager have been conducted by the Secretary.

Richard Rimbach Associates resigned as our advertising representative, and Mr. Jack Bain has been handling this work since. As our members will note from the increased advertising activity in the JOURNAL, this has been advantageous.

Miss Eleanor Reid, our Managing Editor, resigned. This resignation was necessary since Miss Reid was married to Mr. Brian Forrow and moved to the West. Mrs. Ruth Sterns was appointed Assistant Editor, and has been handling the duties carried on by Miss Reid in an excellent fashion for the large part of the year.

The elected term of office of the Secretary was concluded in May of 1952. At the Philadelphia Meeting, the Board of Directors appointed Henry B. Linford to continue as Secretary on an appointment basis.

HENRY B. LINFORD, *Secretary*

Annual Report of the Secretary

Report on Membership for 1952

Membership as of January 1, 1952	2055	
Qualified as members in 1952	242	
Reinstated members	7	
Total		2304
Deaths during 1952	10	
Resignations and members dropped in 1952	141	151
Membership as of December 31, 1952		2153
Net Increase		98

Composition of Total Membership, January 1, 1953

	Active	Associates	Student associates	Total
United States	1787	66	30	1883
Canada	62	2	1	65
England	37	1	0	38
India	31	5	2	38
Other Foreign	126	3	0	129
Total	2043	77	33	2153
Emeritus				36
Honorary				9
Sustaining				75
Grand Total				2273

Sustaining Memberships

Sustaining member companies and total number of memberships as of May 1, 1952	66
Sustaining member companies as of April 8, 1953	81
Total sustaining memberships (including multiple memberships by some companies) as of April 8, 1953	94

Modern Electroplating

Modern Electroplating on hand January 1, 1952	82
Modern Electroplating sold during 1952	82
Modern Electroplating on hand Dec. 31, 1952	0

Report of Tellers of Election

For President: R. J. McKay, 740; 8 write-ins; 12 abstentions

For Vice-President: Hans Thurnauer, 305; Jerome Strauss, 297; 147 write-ins; 11 abstentions

In addition to the above, 10 ballots were declared illegal because of irregularities.

(Signed) HERBERT P. DENGLER, *Chairman*
IRVING MOCH, JR.
DAVID O. FEDER
Tellers of Election

The Tellers' Report was unanimously accepted and a motion was made declaring the candidates, R. J. McKay (President) and H. Thurnauer (Vice-President), duly elected.

HENRY B. LINFORD, *Secretary*

TREASURER'S REPORT* FOR 1952

* *The Auditor's Report appeared in the May 1953* JOURNAL.

Canadian Convention Fund (in Canadian Funds)

Bank Balance 1/1/52		$1,104.20
The Canadian Bank of Commerce, Toronto		
Transferred to the Montreal Branch June 2, 1952		
Credit: Deposits		6,970.18
		8,074.38
Debit: withdrawals to 12/11/52		5,051.30
		3,023.08
Debit: withdrawal for draft of $3,108.50 in USA—Funds—12/18/52		3,023.08
Bank Balance 12/18/52		0.00

The draft for $3,108.50 in USA funds was deposited in the National City Bank, New York City, to the credit of The Electrochemical Society.

Columbus Convention Fund

USA Gov. Bonds Series F (earmarked in safe deposit box		400.00

CORN EXCHANGE BANK
102nd Street and Broadway, New York, N. Y.

Corrosion Handbook Fund—for 1952

Total Corrosion Handbook Fund, 1/1/1952		$12,399.83
Corn Exchange Bank		
USA Savings Bonds Series F (earmarked in safe deposit box)		10,471.37
New York Savings Bank		
Balance, 1/1/52		1,928.46
Credit: Interest for 1952	$58.43	
Royalties for 1952	1787.40	1,845.83
		3,774.29
Debit: Prizes, Travel Expenses, Medallic Art Co., etc		491.38
Balance, 1/1/53		3,282.91
Total Corrosion Handbook Fund, Jan. 1, 1953		13,754.28

Edward Weston Fellowship Fund—for 1952

Total Weston Funds available for Fellowship 1/1/52		$2,296.91

* *Capital Funds Securities, 1/1/1953*

$11,881.88—Hanover Bank Co., Trust Fund A—purchase price 5/2/51 for 1160 units; value 1/1/1953—$12,303.19

$1,836.66—AC 1330 Brook Avenue, Bronx N. Y., N.Y.T. & M. Co.

1 —Prudence 422 34 E. 86th St., N.Y.C. allowed claims.

* The Hanover Bank, Trustees
70 Broadway, New York, N. Y.

The Hanover Bank, *Trustees*		
Principal Account Balance 1/1/1952	$57.31	
Principal Account Balance 1/1/1953	57.31	
Checking Account Balance 1/1/1952		$1,460.36
Credit: Deposit from Income Acct. 9/11/52		365.92
		1,826.28
Debit: ECS Consolidated Fellowship Fund 12/23/52		1,800.00
Checking Account Balance 1/1/1953		26.28
Income Account Balance 1/1/1952		93.36
Credit: Dividends from H.B., C.T. Fd. A. for 1952		388.62
		481.98
Debit: Trustee charges for 1952	$ 19.26	
Transfer to checking acct. 9/11/52	365.92	385.18
Income Account Balance 1/1/1953		96.80
The Hanover Bank Balance for Fellowship 1/1/53		$ 123.08
Seamen's Bank for Savings		
Income Balance 1/1/1952	$1,042.35	
Credit: Interest for 1952 to 12/23/1952	13.03	$1,055.38
Debit: withdrawal for Consolidated Fellowship Fund 12/23/52		1,055.38
Income Balance, Dec. 23, 1952		0.00
Total Weston Fund Available for Fellowship, 1/1/53		$ 123.08

Edward Goodrich Acheson Fund—for 1952

*Capital Funds Securities—1/1/1953**

$ 5,000.	USA Savings Bond Series F, no interest; due 10/1/53. Registered.
10,000.	USA 2¼% Savings Bond Series G due 11/1/54. Registered.
2,000.	Pennsylvania Railroad Co. 3½% General Mortgage Bond, Series F. Due 1/1/85.
2,000.	American Telephone & Telegraph Co. 2¾% Debenture due 10/1/75.
52 shs.	American Can Co. 7% Cum. Pfd.
14 shs.	Corn Products Refining Co. 7% Cum. Pfd.
10 shs.	Eastman Kodak Co. 6% Cum. Pfd.
10 shs.	Ingersoll Rand Co. 6% Cum. Pfd.
25 shs.	International Harvester Co. 7% Cum. Pfd.
20 shs.	National Lead Co. Class A 7% Cum. Pfd.
1	Sealed envelope containing Lawyers Westchester Mtge. & Title Co. Guaranteed First Mortgage Participating Certificate, Series 2-7165 Bond & Mortgage. Only remaining asset is General Claim.
1	Sealed envelope containing Lawyers Westchester Mtge. & Title Co. Series 3-6902 due 3/1/38. 5½%
1	Sealed envelope containing Lawyers Westchester Mtge. & Title Co. Guaranteed First Mortgage Certificate in Bond & Mortgage of Chatsworth Gardens Corp. Series 6-6972 Certificate $296. Only remaining asset is General Claim against the former guarantor.

* Guaranty Trust Company of New York, Custodian. Fifth Ave. at 44th St., New York, N. Y.

Acheson Fund Total Balance 1/1/1952	$1,092.33

TREASURER'S REPORT FOR 1952 (*continued*)

Guaranty Trust Co., *Custodian*

Income Balance, 1/1/1952 (includes Prin. Fds. of $97.43)		3,372.99
Credit: Dividends plus interest		991.50
		4,364.49
Debit: Custodian Charges	$ 77.00	
Honorarium to J. W. Marden	1,000.00	
Medallic Art Co.	432.77	
Medallists Expenses	107.10	
Consolidated Fellowship Fund	2,000.00	3,616.87
Income Balance 1/1/1953 (includes Prin. Fds. of $97.43)		747.62

East River Savings Bank, Amsterdam Ave. at 96th St., N.Y.C.

Principal Funds Balance, 1/1/1952	719.34
Credit: Interest for 1952	17.16
Principal Funds Balance, 1/1/1953	736.50
Acheson Fund Total Balance, 1/1/1953	1,484.12

Roeber Research Fund

Bank Balance, 1/1/52	$5,209.39
Credit: Interest for 1952 to 12/18/52	58.60
	5,267.99
Debit: Consolidated Fellowship Fund 12/18/52	5,267.99
Bank Balance, 12/18/52	0.00

The Roeber Research Fund was incorporated into the Consolidated Fellowship Fund by directive of the Board of Directors. Oct. 26, 1952

East River Savings Bank
Amsterdam Ave. at 96th St., New York, N. Y.

Joseph W. Richards Memorial Fund

Bank Balance, 1/1/52	$3,657.48
Credit: Interest for 1952	73.52
	3,731.00
Debit: Consolidated Fellowship Fund 12/18/52	3,000.00
Bank Balance, 1/1/53	731.00

Central Savings Bank
Broadway at 73rd St., New York, N. Y.

(*Continued from page 202C*)

salt spray exposure. The new chemical forms an amorphous mixed metallic oxide coating of low dielectric resistance that provides high corrosion-resistance for unpainted aluminum. Also it forms an excellent paint bond. American Chemical Paint Co. N-17

LITERATURE FROM INDUSTRY

Mono-Column Demineralizer. Catalogue sheet describes Penfield's new M-100 Mono-Column Demineralizer. Photograph and schematic diagram, combined with detailed description of parts, sample specifications, and performance data, provide a concise and complete resume of essential information. Penfield Manufacturing Co., Inc. P-139

New Manuals. Two new manuals, "Constant Temperature Control" and "Constant Pressure Control," have been published. The former is a guide to control devices of specialized design; 64 pages, extensively illustrated. The latter manual explains effective means of achieving automatic vacuum and pressure control. Emil Greiner Co. P-140

Rustproofing Agent. New product to prevent rusting of steel, cast iron, and other iron alloys during storage is described in technical bulletin. The product, a free-flowing powder, is a mildly alkaline, water-soluble material used in a concentration of 1 oz/gal. Tests indicate that it will protect iron and steel against rusting in 100% humidity for several weeks or more. Available in 100- and 300-lb fiber-packed drums. Enthone, Inc. P-141

Germanium Diodes. Bulletin describes characteristics and advantages of the new line of Germanium Diodes being produced. This company is first to produce a vacuum-impregnated Diode. These are the result of two years of development and pilot production. International Rectifier Corp. P-142

Tank Rheostats. New bulletin describes and illustrates the new H-VW-M tank rheostats. Lists standard ratings and sizes of rheostats, which are used to adjust current density in plating tanks. A schematic drawing shows a typical rheostat-to-tank hookup. Hanson-Van Winkle-Munning Co. P-143

Liquid-Level Control. Folder describes a single-thyratron electronic liquid-level control operating without radio frequency from a single capacitive type probe. Illustrates the single-unit control, probe, and alternative schematic arrangements for installation. Thermo Instruments Co. P-144

Electric Heater. Bulletin describes new Glo-Quartz Electric Radiant Immersion Heater which makes it possible to heat all acid electroplating, electropolishing, pickling, and phosphatizing solutions with 100% efficiency. Long life, portability, and replaceable heating elements are some of its advantages. Glo-Quartz Electric Heater Co., Inc. P-145

To receive further information on any New Product or Literature from Industry listed above, send inquiry, with key number, to JOURNAL of The Electrochemical Society, 216 West 102nd Street, New York 25, N. Y.

Please print your name and address plainly.

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Editorial

"Gypping" the Gullible

A *GULLIBLE* public spends fantastic sums every year for all sorts of devices and packaged chemical magic that guarantee to improve performance, extend life, or save money. Among the more notorious examples are battery additives, unproven lubrication additives, pills to "pep-up" the motor, etc. The most widespread of these panacean products of late are gadgets to prevent corrosion in water systems and scale formation in boilers. These so-called electrical, magnetic, or catalytic devices are widely sold for installation in water pipes or boilers and "guarantee" the purchaser immunity from further corrosion or scale troubles. One manufacturer promises, in addition, to kill the "larvae of bacteria" that somehow manage to escape destruction in the usual treatment of water for human consumption. Unfortunately the nontechnical layman is sometimes impressed by such pseudoscientific nonsense as the following, quoted from one manufacturer by Professors Eliassen and Uhlig in their discussion of these schemes.* "[This unit] creates that neutral corpuscle of electricity creating physical change. When an atom loses one or more of its electrons, it becomes incomplete and immediately joins another of like or different material in order to complete its circle of electrons. [The unit] makes inert those elements that cause corrosion or destruction. [The unit] makes positive those elements that become inert under heat, pressure, and cold, thus eliminating scale formation as these particles remain minute in solution."

Beyond the fact that these devices are not based on any recognized scientific principles and lack proven merit, lies the danger that their use may lead to a false sense of security. Where competent engineering examination and advice might have prevented trouble by suggesting suitable protective measures, reliance upon mysterious catalysts or "electronic" units may result in disastrous losses. Large corporations, as well as private householders, are being victimized by the persuasive promises of large savings. A nuisance aspect is the absurd request made in some localities that utility companies modify grounding installations to avoid interference with the performance of these devices. In other cases, magnesium anode installations have been blamed for the failure of these magical devices to function as represented.

Elsewhere in this issue a statement by the Inter-Society Corrosion Committee urges great caution in the use of these unproven cure-alls. This statement deserves wide dissemination. It is to be hoped that information from such sources will aid better business organizations in ferreting out and exposing concerns in their midst that, under the guise of respectable small businesses, would prey upon the technical ignorance of the public.

—R. M. BURNS

* R. Eliassen and H. H. Uhlig, *J. Am. Water Works Assoc.*, **44**, 576 (1952).

Now a new synthetic helps dial telephone service

In a large, modern telephone office, two million relay contacts await the orders of your dial to clear a path for your voice. They open and close a billion times a day.

Unrolled view (one-third size) of capacitor unit wound with "Mylar." The transparent film is only 0.0005" thick yet stands handling without breaking.

Among the elements that guard your dial telephone service are electrical capacitors. They help prevent the formation of arcs that pit and may eventually destroy relay contacts. But millions more of these capacitors are needed each year. How could they be made less costly?

Bell Laboratories engineers, on the lookout for new materials, became alert to the possibilities of the new "Mylar" polyester film. A product of the Du Pont Company, "Mylar" is chemically the same as Du Pont's "Dacron" polyester fiber used to make fabrics. Bell engineers discovered that it also had remarkable dielectric properties—of just the right kind to help their capacitor problem.

The film takes the place of impregnated paper formerly used to separate the metal foil electrodes. It is tougher, stands more voltage and needs no impregnation. The new capacitors require no protective housing and are *much* smaller and less costly.

Here is another example of the way America's technology advances through the sharing of knowledge. Just as Bell Telephone Laboratories makes many of its discoveries—the Transistor, for example—available to other companies, so does it adapt the inventiveness of others when it can help your telephone service.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields

THE MILWAUKEE-CHICAGO-GARY INDUSTRIAL AREA

O. W. Storey[1]

The electrochemical industry in this "Crossroads-of-the-Nation" region not only embraces a wide variety of activities but it also is of economic importance. Its significant role in this region often is overlooked both because of the region's large over-all industrial production and the virtual absence of any individually large and spectacular electrolytic and electrothermal operations such as are found in some of the other electrochemical centers. The many electrochemical operations in this area, with a few exceptions, are mostly either relatively small or they are of the "captive" type, thereby being submerged in a larger over-all operation. Nevertheless, this region is in the forefront in the fields of electrodeposition, electrometallurgy, the rare metals, and electronics, and is not without its electrolytic industry.

The region covered in this article extends along about 150 miles of the southwestern shore of Lake Michigan from Milwaukee on the north through Chicago and Gary to Michigan City (Indiana) which is close to the Michigan-Indiana boundary line. Inland it extends approximately 75 to 100 miles from Chicago. That part which is relatively close to Lake Michigan is highly industrialized. It contains over 20,000,000 tons or about 20 per cent of the steel-making capacity in the United States. It is at the top of the nation's industrial centers in production of electrical and nonelectrical machinery, electronic equipment, fabricated metal products, railroad equipment, iron and steel foundry products, and such appliances as electric ranges, refrigerators, shavers, and freezers. In addition, this area is the world's leading food-processing center. Others of importance include the chemical, petroleum-refining, printing and publishing, furniture, paper products, leather, instruments, and brewing industries.

The Chicago metropolitan area (Cook, DuPage, Kane, Lake, and Will Counties in Illinois, and Lake County in Indiana) did an estimated total business of over 36 billion dollars in 1952 with a factory output of over 15 billion dollars, despite the steel strike. Milwaukee County, which ranks eighth among the nation's industrial areas and is the third largest consumer of steel, in 1952 did an estimated total business of nearly 5 billion dollars with a factory output valued at 2 billion dollars. In 1952 and in the seven years ended last December 31, the Chicago metropolitan area led all others in the country in number and value of contracts awarded for construction of large industrial plants valued at more than $100,000 based on reports published in *Engineering News-Record*. For the seven years the total was $457,544,000. In 1952, out of a total of 536 such contracts for the entire country, 65 were for this Chicago metropolitan area and had a value of $137,124,000. The factors contributing to the large and steady growth of industry in the Milwaukee-Chicago-Gary region and the continuing influx of new industries into it include geographical location, excellent transportation facilities, the productive soil of the surrounding regions, excellent health conditions, abundance of raw materials, and proximity to fuels and iron ores.

[1] Regional Editor, Chicago. 180 North Wabash Avenue, Chicago, Illinois.

The excellent rail transportation facilities of the region are well-known. Nineteen trunk rail lines together with 15 belt, terminal, and industrial railroads, and a switching district with 7850 miles of track make Chicago the railroad center of the nation. Milwaukee has three trunk rail lines entering it directly and three other lines entering it by ferry across Lake Michigan from Michigan ports. Nine car ferries are employed in this daily round-the-year service. Chicago is also the hub of the nation's hard-road system carrying more than 500 common-carrier truck and bus lines.

Supplementing the land transportation systems are the water-borne systems utilizing Lake Michigan, the other Great Lakes, and the inland navigable waterways, the latter connecting Lake Michigan with the Mississippi River system by way of the Sanitary and Ship Canal, Calumet Sag Channel, and Illinois River. Ocean shipping, including the ships of six foreign steamship lines, reaches Chicago, Milwaukee, and the other Lake Michigan cities by way of the Welland Canal and the St. Lawrence River. The Chicago harbor district alone normally handles more traffic than does the Panama Canal and one-seventh as much as all the combined seaports of the United States. Forty-six million tons of lake-borne traffic and 18 million tons of river-borne traffic were handled in the Chicago harbor district in 1952. In addition, Milwaukee's harbor handled nearly nine million tons of lake-borne traffic. The low cost bulk transportation afforded by the Great Lakes, supplemented by that of the inland waterways, is a most important factor in the industrial growth of this region. The Minnesota and Upper Michigan iron ores are transported cheaply to the blast furnaces of the Chicago-Gary area. Limestone and the eastern coking coals are transported over the Great Lakes to the blast furnaces and coke ovens; Southern Illinois coals and oil are transported by barge over the inland waterways to the Chicago power plants and refineries. The barges also handle petroleum products, limestone, cement, chemicals, sand, gravel, and grain. Likewise, the products manufactured in this area are transported cheaply over the waterways and lakes to the consumer. Consequently, the area adjacent to the Sanitary Canal, particularly in the Joliet region, is highly industrialized. Many Chicago area chemical plants are located here.

Other forms of commodity transportation contributing to the growth of this area are the many pipelines bringing in natural gas and oil from the producing sections which extend from southern Illinois to Texas. The pipeline network also reaches Wyoming in the northwest. Furthermore, a network of pipelines, extending out from the refineries, transports the refined products to consumers, some of these lines being over 500 miles long. At the end of 1952, the pipelines bringing oil into the refineries of the nine companies operating in the Chicago area had an estimated daily capacity of 565,000 barrels. In addition to that brought in by tank cars, nearly 50,000 barrels are transported daily in tank vessels operating on the Illinois River waterway and the canal. This area is also in a strategic position with respect to the rapidly developing Canadian gas and oil fields from which a pipeline

now reaches the head of the Great Lakes; from there tankers may transport it to the refineries.

Not only is Lake Michigan a valuable asset because it provides the cheap transportation for raw materials and finished products moving in and out of the Milwaukee-Chicago-Gary area, but it also is assuming more importance as a vast and readily accessible supply of the high-quality water required in quantity for many industrial operations. The value of this asset probably will be more fully realized by industry in the not-too-distant future, although at present this area also has good sources of water in its numerous rivers and streams and an excellent underground supply.

Supplementing the transportation facilities of this region are its excellent electric power facilities. Unlike most of the electrochemical centers of the United States, substantially all of the electric energy is derived from steam-driven power plants, the primary fuel sources largely being coal, but oil also is used. There are a few relatively small hydroelectric plants in Wisconsin.

The northern third of Illinois, including all of the Chicago suburban area lying within Illinois, is served largely by the Commonwealth Edison electric power system. In March of 1953 it had a production capacity of 3,062,000 kw with an additional 851,000 kw under construction, or on order. The Commonwealth's electric power distribution system, extending from Lake Michigan to the Mississippi River, has its large power stations so located that a number of them can take full advantage of barge transportation of coal over the inland waterway system from mines in downstate Illinois. They also are close to the extensive supplies of oil available at the large oil-refining plants in this area. As a result, industrial power costs compare very favorably with other industrial regions where steam plants are used to generate power.

In the Wisconsin part of this region, the Wisconsin Electric Power Company serves the eastern section of Wisconsin, the municipal system of the City of Milwaukee buying its power from this company. Its production capacity is 834,000 kw with 240,000 under construction.

The northwestern part of Indiana is served by the Northern Indiana Public Service Company which has a generating capacity of 227,000 kw.

To the power generated by the public service companies must be added the large amounts of power generated by the Chicago-Gary steel companies chiefly to meet their own requirements.

Natural gas has been distributed in Chicago for many years and has been piped into the Wisconsin area since the end of World War II.

The extent of the Chicago area market which supports its large industrial development arises from the fact that Chicago is close to the center of population of the United States and that within a 500-mile radius live more than 60,000,000 people. Of these, 5,500,000 live in Chicago and its suburbs and over 1,000,000 live in Milwaukee County and the lake shore cities between Milwaukee and the Wisconsin-Illinois boundary line.

The effect of the rich agricultural region adjacent to this area is emphasized in the case of the chemical industries, which will be discussed elsewhere in this article. However, the impact of agriculture was very marked at an early date in the mechanical industries. When this vast farming area began to grow rapidly about a century ago there was a tremendous demand for farm implements, equipment for the expanding railroads, and machinery for the flour and saw mills. It was then that the superior mechanical skills of the persons that came to this area made itself felt and the foundations for the mechanical industries were laid.

The survey which follows is devoted to a more detailed discussion of the various branches of the electrochemical industry of this region. This is followed by a brief survey of the closely related chemical and pharmaceutical industries.

Electrodeposition of Metals

The industrial electrodeposition of metals in the Milwaukee-Chicago-Gary region may be divided into three fields: electroplating, electroforming, and electrorefining. The large number of electroplating establishments, many of which have a high volume of production, make electroplating by far the most important of the three. Furthermore, the operators of these establishments state that Chicago is the center of the general electroplating industry in this country with a production volume considerably exceeding that of the balance of the country combined. "General" plating is distinguished from the highly specialized plating for automobiles which is characteristic of the Detroit area.

In addition to the large volume of general electroplating done in the Chicago area, there is also a large volume of continuous electrogalvanizing and electrotinning of wire, strip, and screen.

The extent of the general plating industry is related directly to the extensive metal-fabricating and machinery industries referred to earlier in this article. The U. S. Department of Commerce, in its 1947 Census of Manufactures, reported 4658 establishments in the Chicago, Milwaukee, and Racine (Wisconsin) metropolitan areas devoted to the manufacture of fabricated-metal products, electrical and non-electrical machinery, and transportation equipment, all of which are actual or potential users of plated metals or make plated products. Many of these plants have plating departments, but the majority are not warranted in establishing their own plating departments, and patronize the general job-plater. As a result, this area supports a large number of general job-platers and it is the nation's center of this business. Of the approximately 300 such plants in this region, about 230 are in the Chicago metropolitan area and 32 in Milwaukee, 6 in Racine, and 12 in Rockford (Illinois) which also is an important metal fabrication and machinery center.

It is difficult to arrive at a quantitative evaluation of the output of the electroplating industry. In the 1947 Census of Manufactures, 205 plating and polishing establishments in the Chicago and Milwaukee metropolitan areas had 4078 employees, paid $12,342,000 in wages, and added $19,544,000 in value through their operations. The Chicago Electro-Platers Institute reported as of March 1, 1951 that 79 of its 102 member job-plating firms (the membership represents most of the larger job-platers) normally employed 2958 (maximum 3787), used 568,111 gal (maximum 680,000) of plating solutions and 1,340,530 amp (6–12 volt generators and various types of rectifiers) in 2100 plating tanks (up to 62 ft in length). The plating solutions were divided percentagewise among the several metals as follows: cadmium 12.26, copper 14.07, zinc 17.41, nickel 37.12, chromium 15.23, silver 0.96, brass 2.55, and others 0.40. Job-platers use "still" tanks for a large proportion of their work.

The electroplating departments of the companies that do their own plating may be divided conveniently into three types which are: (*a*) still tank in which a multiplicity of separate items are plated; (*b*) plating done in barrels, semi-automatic, or fully automatic plating machines; and (*c*) continuous plating of wire and strip or similar material. In the first two categories, a wide variety of metals is electro-

deposited, whereas in the third the metals are usually limited to tin and zinc, the plating department generally being part of a steel-mill operation.

Plating departments of the second category are found in the plants of the larger manufacturers of, for example, plumbing goods, hardware, metal furniture, bicycles, motorcycles, household appliances, automotive parts, electrical goods, and electronic devices. Fully automatic plating machines and barrels usually are used for a large part of the production. A few of the manufacturers in this group are: Western Electric Company; Hotpoint, Inc.; J. P. Seeburg Corporation; Croname, Incorporated; Sloan Valve Company; International Rolling Mill Products Corporation; Crane Company; Sunbeam Corporation; Illinois Watch Case Company; Cutler Hammer, Inc.; McGraw Electric Company; Admiral Corporation; Motorola, Inc.; Allis-Chalmers Manufacturing Company; Harley-Davidson Motor Company; Arnold, Schwinn & Company; and Kulhne Manufacturing Company.

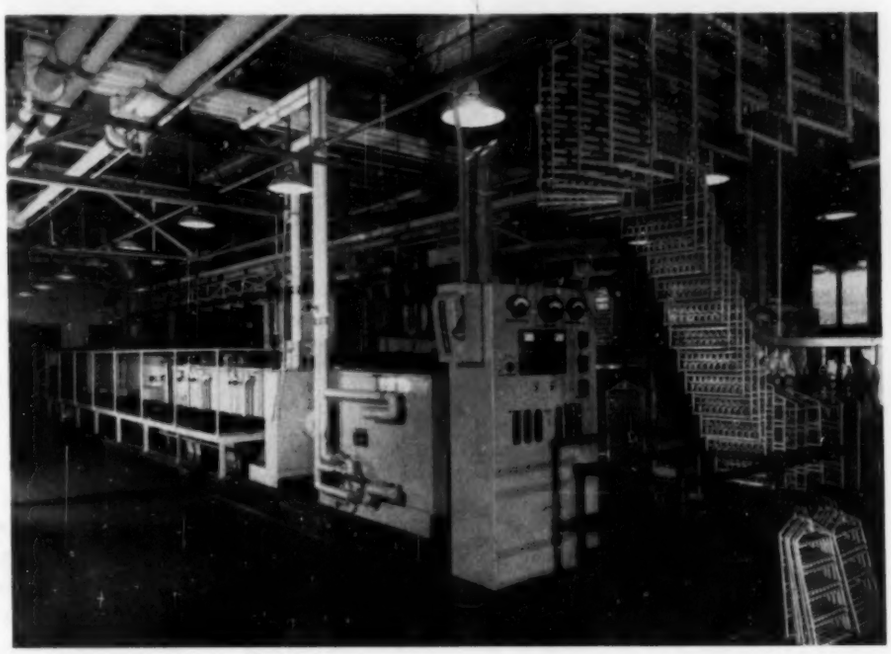


FIG. 1. Automatic chromium plating machine with associated conveyors for handling racks of work at Western Electric Company Hawthorne Works, Chicago.

Some indication of the size of some of the "captive" electroplating and finishing operations may be gained from that of the Sunbeam Corporation, manufacturer of electrical appliances. The plating department contains nine fully automatic plating machines which account for 95 per cent of the total production. The finished plated area of the products, some of which are subject to three plating operations, is in excess of 1,000,000 ft² per month. There are about 500 employees in the finishing department, which includes, in addition to the plating operations, cleaning, grinding, polishing, buffing, coloring, and organic finishing. Copper, gray and bright nickel, decorative and hard chromium and zinc are plated, with the zinc area the smallest.

Another large electroplating operation is at the Hawthorne Works which is the largest manufacturing unit for Western Electric's principal commodity—communication equipment. At present the two principal products made at Hawthorne are automatic central office switching equipment and telephone cable. Electrochemistry plays an important part in the manufacture of these products.

Approximately 16,000,000 ft² of surface area per year are finished by electroplating. These finishes are applied on central office equipment for functional rather than decorative purposes. An estimated 80 per cent of this total area is zinc-plated and passivated to provide protection against corrosion. A composite finish of nickel and chromium is plated on relay cores and armatures to improve their wear resistance. A copper and tin finish is plated on parts to facilitate solderability, while silver or gold-plated finishes are used to reduce electrical surface resistance. Millions of parts with close-specifications requirements are processed efficiently by barrel plating and conveyorized handling of racked work.

Of special interest is the automatic plating machine at the plant of the International Rolling Mill Products Corporation in which both the interior and exterior surfaces of electrical conduit are electrogalvanized. In this installation, designed by The Meaker Company, the interior of the conduit is plated by means of an insoluble anode which travels with the conduit.

The plating and, particularly, the electrogalvanizing of small hardware are an important part of the electroplating industry in this area. The following described operations of one of the large steel companies are typical. At its Joliet plant this company has a capacity of six tons per week for the barrel-plating of nails with zinc and also tin, cadmium, and copper. At its North Chicago plant, it has an additional capacity of five tons per week for plating bolts, nuts, and rivets.

The continuous electrotinning of strip steel for the production of tinplate received its big impetus early during World War II, when it became necessary to cut down the use of tin drastically after the Japanese cut off the southwest Pacific sources of supply. The electrotinning effected a large saving of tin over the hot-dip process. It is now being used extensively for producing tin plate required for the cans largely used for preserving fruit and vegetables. Much of this tin plate is consumed by the many plants in this area which produce cans for the great number of vegetable- and fruit-canning plants of the Midwest. In the electrolytic production of tin plate, the plating operation is followed immediately by a heating operation in which the freshly plated strip is heated sufficiently to fuse the tin coating and cause it to flow slightly (1).

Electrogalvanizing and electrotinning of strip, wire, and screen cloth are carried on by the following companies:

Acme Steel Company, Chicago—6 electrolytic cells for electrogalvanizing strip having an annual capacity of 99,000 tons of galvanized strip 3/8 in. to 18 in. wide. The strip also is electrolytically cleaned.

The Republic Steel Corporation, South Chicago, Illinois—one 40-strand unit for electrogalvanizing wire having an annual rated capacity of 27,000 tons based on the average distribution of product during the year 1952.

United States Steel Corporation, Tin Plate Department, Gary, Indiana—4 electrotinning and fusion lines for plating steel strip. The rated yearly capacity is 540,000 tons of tin plate and these lines require 220,000 amp at 15 volts.

The Youngstown Sheet and Tube Company, Indiana Harbor, Indiana—2 electrolytic tin-plating and fusion lines having an annual capacity of 144,000 to 192,000 tons of tin plate in varying coating weights from 25 to 75 lb per base box.

Because of the magnitude of the electroplating industry, the business of providing platers with equipment, supplies, and services is also of importance. A large number of these suppliers (over 60 in Chicago alone) are selling equipment and materials to the platers. Chicago firms that have developed and are producing fully automatic plating machines are The Meaker Company and Crown Rheostat & Supply Company, with Belke Manufacturing Company making a semiautomatic type. B. Mercil & Sons Plating Company makes (but does not sell directly to the trade) an automatic barrel-plating machine. The Meaker Company also produces and installs continuous wire and strip plating equipment.

A number of laboratories do testing and analytical work almost exclusively for the electroplating industry. Three firms furnish consulting services: Scientific Control Laboratories; Graham, Crowley & Associates; and Platers Technical Service, Inc.

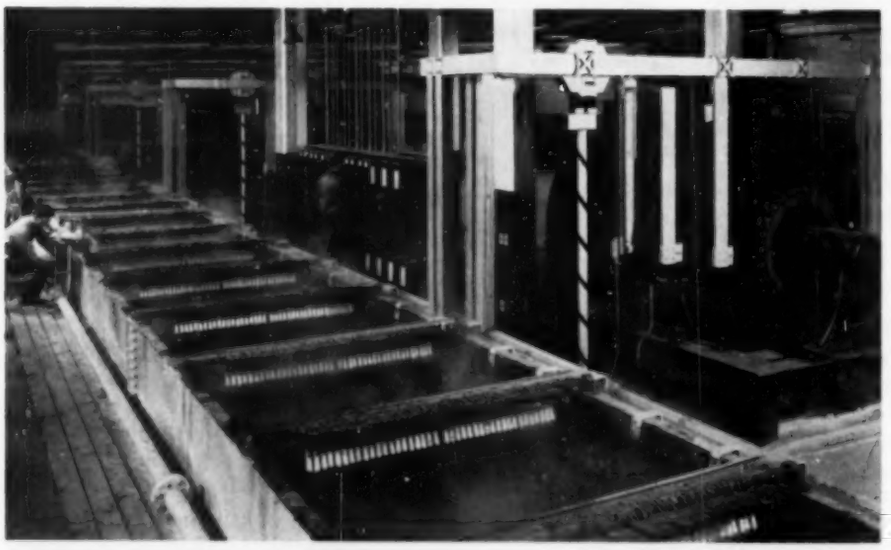


FIG. 2. Continuous 40-strand wire electrogalvanizing unit in operation.

© *The Meaker Company*

Another large steel company has two continuous electrogalvanizing units for wire at one plant (Waukegan, Illinois) and four units for electrogalvanizing screen cloth at a second plant (DeKalb, Illinois). The first plant has a capacity of 195 tons of galvanized wire per week of fifteen 8-hour turns. The second unit has a capacity of 400 tons per week.

Not all plated sheet metal used subsequently in metal-forming operations is coated in continuous strip. The Apollo Metal Works of Chicago and the American Nickeloid Company of Peru, Illinois, are producers of electroplated or "prefinished" metal sheets. The greater flexibility of this arrangement over the continuous plating of strip permits the operator to coat various sizes of metal sheets with a wide variety of metals as demonstrated by the products of these companies.

The plating industry of this region offers a complete service insofar as the number of metals, alloys, and finishes are concerned. In addition a number of establishments oxidize aluminum anodically (anodizing) exclusively. Although the bulk of the business is concerned with the deposition of the more common metals such as nickel, chromium, zinc, cadmium, copper, and brass, the plating of gold and silver for jewelry, watch cases, silverware, and trophies occupies an important place in the industry. All of the following metals, although uncommonly used in the general plating industry, are also electroplated by shops in this region: tin, lead, platinum, rhodium, tin-copper alloy, tin-zinc alloy, and bronze. These plated metals have special applications but, nevertheless, are important to industry.

In the field of electroforming, the Milwaukee-Chicago-Gary region is an important factor because the Chicago metropolitan area is one of the country's top printing and publishing areas. Located here are the well-known Lakeside Press (R. R. Donnelley & Sons Company), W. F. Hall Printing Company, and Cuneo Press (Chicago and Milwaukee). The 1947 Census of Manufacturers listed 1884 establishments with 82,470 employees. Their extensive requirements for the electroformed electrotypes is indicated by the 41 job-electrotypers in Chicago and 5 in Milwaukee. The 1947 Census states that the electrotyping industry for the entire country in one year added $45,799,000 in value by its operations. In Illinois (largely in Chicago) the value added was $13,301,000 or 29 per cent of the country's total. As in the electroplating industry, a number of the larger printing establishments produce their own electrotypes; however, comparative figures are not available. The W. F. Hall Printing Company, whose operations include electrotyping, also prepare copper-surfaced rolls (electroformed) for rotogravure work, etc. This latter operation employs a copper sulfate regeneration cell.

Electroforming other than electrotyping has made some progress, but it is not yet being employed to a significant extent. At least one molder of plastics is electroforming molds of copper for making articles of intricate design for which it normally is difficult and costly to make steel dies; and at Elkhart, Indiana, C. G. Conn, Inc., is electroforming certain band instruments, such as kettle drums and the bells for the larger wind instruments. Some electroforming is also done for salvage purposes in which worn, undersized, or damaged

surfaces are built up by electroplating, particularly with nickel.

The only lead-electrorefining plant in the United States is located in East Chicago, Indiana. It is operated by U.S.S. Lead Refinery, Inc., a subsidiary of United States Smelting, Refining and Mining Company, and has a rated capacity of 42,000 tons of refined lead per year. Lead bullion produced in Midvale, Utah, is refined by the Betts lead fluosilicate electrolytic process. The cells operate at about 118°F (48°C) and 0.5 volt. The residual impurities are gold, silver, bismuth, copper, antimony, and tellurium (2).

Goldsmith Bros. Smelting & Refining Company of Chicago electrolytically refine precious metal scrap in an acid chloride bath. Gold of better than 99.9 per cent purity is deposited at the cathode, whereas the other metals, such as silver (as the chloride), platinum, and palladium, remain behind either in the sludge or in solution.

Industrial Electrolytic Operations

The Milwaukee-Chicago-Gary region does not contain any of the large-volume operations that are found in the country's big industrial electrolytic areas, for example, the production of chlorine and caustic, chlorates, calcium carbide, aluminum, and magnesium. Except for the electrorefining of lead, which is classified as an electrodeposition operation in this article, this region in recent years has had only one large electrolytic operation—the production of white lead from metallic lead. And the plant, the only one of its kind in operation in recent years in this country, now owned by the Eagle-Picher Company, apparently is a victim of titanium dioxide pigment progress. It stopped operating early in 1953 and apparently will not reopen. The plant, located in East Chicago, Indiana, was put in operation in January 1920. It employed the Sperry bi-fluid process involving a porous diaphragm, and had a production capacity of about 10,000 tons per year of dry white lead (3).

The region has but one caustic-chlorine plant and this is a small one with a capacity of a few tons per day, erected to provide supply insurance for a distributor of liquid chlorine. There are, however, a number of special electrolytic operations that are of interest or of technical importance.

The electrolysis of tantalum and columbium salts for the production of the metals is practiced at the plant of the Fansteel Metallurgical Corporation in North Chicago, Illinois. The operations of this company are described in the section on Electronics and Instrumentation.

At the Hawthorne Works of Western Electric Company, copper is electrolytically recovered from acid-pickling solutions used to remove the oxide scale from hot-rolled copper rod used in the manufacture of copper wire. The large quantities of rod processed make it practicable to circulate continuously the pickling solution through an electrolytic recovery unit. Acid is saved as well as copper, and the contamination of waste water is reduced.

The Security Alloys Company of Chicago operates a plant of nine electrolytic cells in which scrap nickel is anodically dissolved to produce nickel sulfate. This is purified and sold to the plating trade in the form of the hexahydrate. These cells are capable of producing 20,000 lb per week of the hexahydrate. Monel metal has been substituted for the scrap nickel during shortage periods, especially while that metal was under government controls.

Electrolytic manganese dioxide, suitable for use as a depolarizer in dry cells, is produced at the plant of Burgess Battery Company in Freeport, Illinois. The cyclic process used was put into operation around 1940. The dioxide is deposited at the anode from a manganese sulfate electrolyte which is depleted of its manganese content as its sulfuric acid content increases. To restore the manganese content of the spent electrolyte it is reacted with a manganese compound, soluble in dilute sulfuric acid. This compound preferably is a lower oxide formed by roasting manganese ore under reducing conditions.

The Carus Chemical Company, which has been making potassium and other permanganates since World War I, oxidizes the manganate to permanganate electrolytically at its plant in LaSalle, Illinois.

Cerium metal and rare earth metals are prepared at the plant of the Lindsay Chemical Company in West Chicago, Illinois, by the electrolysis in iron pots of the fused chlorides in a melt containing calcium, sodium, or potassium chlorides. In the production and separation of the rare earth compounds which are made from the monazite sands, cerium in sulfate and nitrate solutions is conveniently oxidized electrolytically in cells which do not contain diaphragms (4).

The Vulcan Detinning Company is building a detinning plant in Gary for recovering tin from tinplate scrap by the caustic soda process. The tin is to be recovered by electrolysis of the stannate solution formed by the dissolving of the tin from the scrap in a caustic soda solution containing an oxidizing agent.

The research and development laboratories of Great Lakes Carbon Corporation are located in Morton Grove, Illinois, a Chicago suburb. Although its calcining plants are located on the south side of Chicago and in Lockport, Illinois, it produces carbon and graphite electrodes in Niagara Falls and in Morganton, North Carolina.

The plant of the Delanium Carbon Company, owned jointly by Great Lakes Carbon Corporation and Powell Duffryn Carbon Products Ltd., also is located at Morton Grove. It manufactures graphite heat exchangers, absorption and scrubbing towers, and other graphite products.

The Becker Brothers Carbon Company has been making a variety of carbon products in its Cicero plant since 1890. This company makes carbon in various extruded and molded shapes, and specializes in the manufacture of graphite and metal-graphite brushes, welding electrodes, and welder brushes.

Of particular interest to the industrial electrolytic (and other electrochemical) industries is the manufacture by Allis-Chalmers Manufacturing Company in Milwaukee of mercury-arc rectifiers.

Electrometallurgy

The metal industry in this region uses many electric furnaces both in the production of steel, particularly alloy steels, and in foundries for the production of both ferrous and nonferrous castings. In differentiating the furnaces used for steel production from those used in foundries for the production of castings, the classification appearing in the Standard Metal Directory has been followed (5).

At the beginning of 1952 over 20,000,000 tons of yearly steel-making capacity (5,175,800 net tons being produced in the first quarter of 1953), about 20 per cent of the nation's capacity, as well as nearly 15,000,000 tons (pig iron) of blast-furnace capacity, were concentrated along 15 miles of the Lake Michigan shore extending from South Chicago, Illinois, to Gary, Indiana. Included in this total are 891,000 tons of steel made in 12 electric furnaces.

Nine of the 12 electric furnaces are at the Republic Steel Company's plant in South Chicago. These are Heroult electric arc-type furnaces built by American Bridge Company and

have a yearly total rated ingot capacity of 700,000 tons. Seven are conventional door charge, with a rated annual ingot capacity of 62,500 tons per furnace, and two are the top-charge type, with a rated capacity of 131,250 ingot tons per year per furnace.

Three furnaces, with a capacity of 191,000 tons, are in the U. S. Steel Corporation's South Chicago plant. These furnaces are also of the Heroult type, one being rated at 35 tons (38,200 tons per year) and the other two at 70 tons each (76,400 tons per year); they were made by the American Bridge Division of the Corporation. All are used to produce alloy and stainless steels.

About 15 miles inland from the Lake Michigan shore in Chicago Heights, Illinois, there are two electric furnaces in the plant of the Columbia Tool Steel Company which add 6600 tons to the electric steel-making capacity of this area.

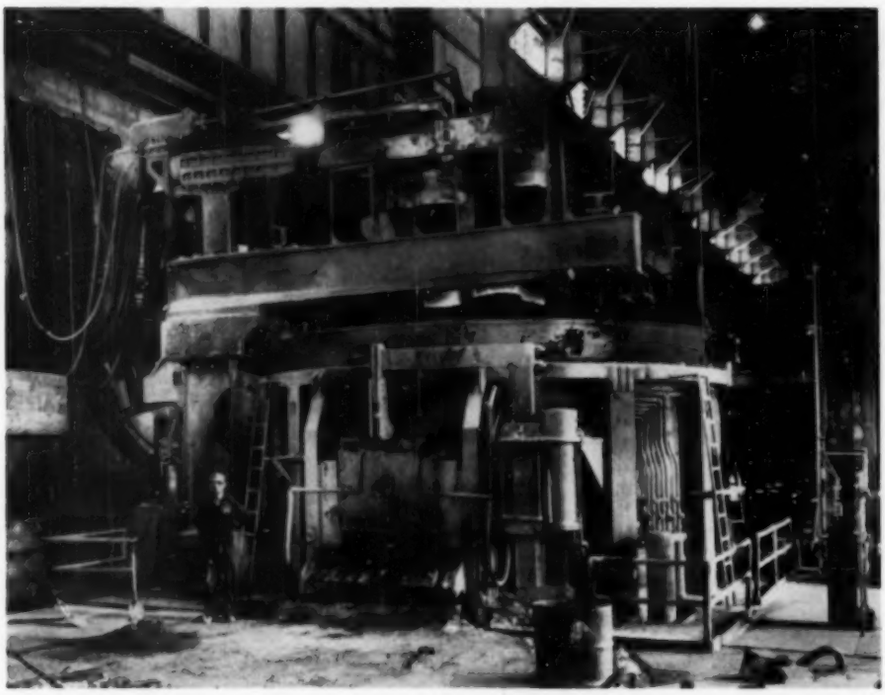


FIG. 3. 125-ton (holding capacity), 22-ft, 35,000 kva electric steel furnace at the plant of the Northwestern Steel & Wire Company, Sterling, Illinois.

© *Pittsburgh Lectromelt Furnace Corporation*

The greatest concentration of electric steel-making capacity in a single plant is on the western fringe of the Chicago industrial area—at Sterling, Illinois, about 100 miles from Chicago. Here, the Northwestern Steel & Wire Company has 5 electric steel furnaces installed with an annual capacity of 825,000 tons, the plant's entire steel-making capacity. All five are Pittsburgh Lectromelt top-charge furnaces, the capacities being one of 20 tons, two of 50 tons, and two of 125 tons. The total yearly steel-making capacity of the 19 electric furnaces in this region is, therefore, 1,722,600 tons.

Supplementing the electric steel-making furnaces are the electric furnaces used largely in foundries for melting iron in its various forms, including alloy steels, for the production of castings. The large number of the electric-melting furnaces indicates the importance of the iron and steel industry in this area. In 42 plants there are 112 of these electric-melting furnaces of various types, including induction furnaces. These are distributed among the three states as follows: Illinois, 22 plants with 62 furnaces; Wisconsin, 14 plants with 35 furnaces; Indiana, 6 plants with 15 furnaces.

In addition to the large number of electric furnaces used for melting iron and steel in foundries, such furnaces are also used extensively in nonferrous foundries in which castings are made of a wide variety of metals, brass and aluminum being the most important. In 11 plants there are 152 electric furnaces used for melting these nonferrous metals.

The Crane Company in Chicago uses the largest number of electric furnaces for any one concern. Its 40 furnaces are used for making castings of gray iron, steel, aluminum, brass, and bronze in the manufacture of plumbing goods and fixtures.

Batteries

Storage batteries are produced at a number of plants, 15 manufacturers being listed for the Chicago metropolitan area by the 1947 Census of Manufactures. There also are several manufacturers in Wisconsin.

Among the Chicago manufacturers are the K. W. Battery Company; Mancha Storage Battery Locomotive Division; Monark Battery Company; Universal Battery Company; and Chicago Forging and Manufacturing Company (battery division). About 50 miles south of Chicago, Gould-National Batteries, Inc., opened, in April 1953, a new 200,000 ft² plant near Kankakee, Illinois, its first in this region. This plant is producing automobile and industrial storage batteries and has increased the Gould production by 20 per cent.

In Wisconsin the Solar Corporation and Globe-Union, Inc., are manufacturing lead-acid batteries in Milwaukee, and the Wisconsin Storage Battery Company is producing them in Racine.

An important segment of the country's primary cell and battery-manufacturing industry is located at the northwestern fringe of the Milwaukee-Chicago-Gary region. Dry cells and other types of primary cells and batteries are made at the plants of two long-established companies, the Burgess Battery Company at Freeport, Illinois, and the Ray-O-Vac Company at Madison, Wisconsin.

Electronics and Instrumentation

The close relationship between the electronics industry, instrumentation, and electrochemistry is pointed out in the May 1952 issue of the JOURNAL. These are again combined in the following description of the electronics and instrumentation aspects of the electrochemical industry in the Milwaukee-Chicago-Gary area. This region is an important center for

these activities and its rapid growth was further accentuated by the more recent widespread use of television. The Chicago Association of Commerce early in 1953 placed Chicago at the top of the country's industrial centers in production of electronic equipment.

Chicago has long been an important center for the production of equipment for the communications industry, probably because the plant of the Western Electric Company, now of immense size, was located here before the turn of the century. A number of other important companies in this field are also located in Chicago, particularly Kellogg Switchboard and Supply Company and Automatic Electric Company. The communications industry, augmented from time to time by developments growing out of continuing major discoveries in the electronics field, has grown to be a most important factor in the industrial development of this region. Instrumentation has also grown rapidly, as it, too, has benefited greatly by these same discoveries and developments.

Although exact information is not available on the electronics industry, some indication of its scope in this region may be obtained from the 1947 Census of Manufactures. The 199 establishments of the communications equipment industry of the Chicago metropolitan area at that time had 80,432 employees and the value added by the manufacturing operations amounted to $416,932,000. Similar information is not available for the Milwaukee area. At the beginning of 1953 the Chicago Association of Commerce reported that in the Chicago metropolitan area the "electric and electronic" industry had 130,000 employees in 600 shops. It further stated that this industry had a 411 per cent increase in the period from 1939 through 1951 and that a large part of the increase "is the result of the spectacular rise in output of television sets and electronic apparatus, lines in which Chicago has no equal as a producer. Virtually all companies in the group have undertaken big expansion programs in the postwar period." This industry apparently is destined to expand further through the introduction of the transistor.

The extent of the industry in this region is indicated by the number of well-known corporations that have plants located here. These include: Western Electric Company; Admiral Corporation; Allied Radio Corporation; Delco Radio Division (Chicago Auto Radio Plant) of General Motors; Hallicrafters Company; Motorola, Inc.; Sentinel Radio Corporation; Wells-Gardner & Company; Trav-Ler Radio Corporation; Raytheon Manufacturing Company; Zenith Radio Corporation; Fansteel Metallurgical Corporation; American Television, Inc.; Scott Radio Laboratories, Inc.; Stewart-Warner Corporation; Jensen Manufacturing Company; Webster-Chicago Corporation; General Instrument Corporation; Radiation Counter Laboratories; Nuclear Instrument and Chemical Corporation; DuKane Company (all in Chicago urban and suburban areas); Webster Electric Company of Racine, Wisconsin; the X-ray Division of the General Electric Company; and the Centralab Division of Globe-Union, Inc., in Milwaukee.

Many manufacturers of component parts for electronic devices are also located here. The manufacture of one of these parts, the electrolytic condenser or capacitor, is of particular interest to the electrochemist. The large demand for condensers of all types results in a considerable volume of business. There are 16 manufacturers of condensers in the city of Chicago, as well as a number of additional producers in the rest of the Milwaukee-Chicago-Gary region.

Of particular interest are the operations of the Fansteel Metallurgical Corporation which not only makes rare metals used in component parts, but also makes electronic devices. A brief description of the Fansteel operations follows (6).

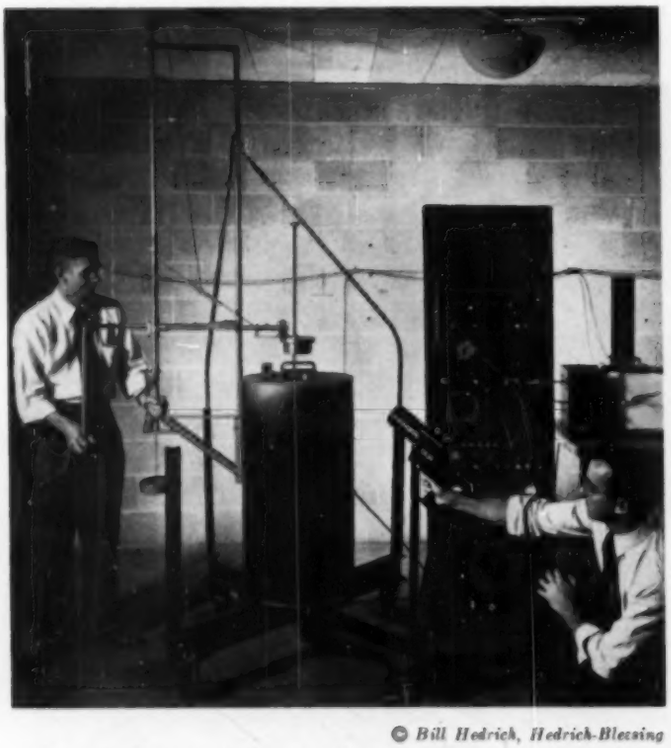
The production of the refractory metals, tungsten, tantalum, molybdenum and columbium, from their ores and their fabrication into useful forms has been carried on by the Fansteel Metallurgical Corporation in North Chicago (over 500,000 ft² of floor space) since about 1914. The industry is based primarily upon the early research work of Dr. Clarence W. Balke at the University of Illinois. The chemical ore extraction and purification operations for the production of the pure salts of the above metals are followed by reduction operations, directly by hydrogen at elevated temperatures in the production of tungsten and molybdenum, and by electrolysis in the production of tantalum. Electrolysis has been used also in the production of columbium. The resultant powdered

FIG. 4. Aerial view of the Fansteel Metallurgical Corporation, North Chicago, Illinois.

metals are sintered into massive metal which may then be shaped or rolled into bars, sheets, and wire. The sintering operation causes appreciable refining of the metal. Fansteel not only produces the primary metals, but also fabricates part of its output into equipment, some of which is based on electrochemical phenomena. It has manufactured the tantalum rectifier since 1924, this being the first practical rectifier for charging railway signal batteries. A selenium rectifier is also made. Tantalum is used as a material of construction in the chemical industries where its insolubility in acids makes it an important material of construction in heat transfer equipment. Other products are electrical contacts and assemblies, welding electrodes, tungsten targets for x-ray tubes, and tantalum electrolytic capacitors and surge arrestors. Of particular interest are the refractory metal alloys that it has developed as well as the carbides which are so important to the metal-working industry. The Fansteel laboratories in 1930 made the fundamental discovery that tantalum carbide (and also columbium carbide) imparts a peculiar "self-lubricating" effect when added to tungsten carbide. A recent development is the siliconized coating for molybdenum which permits the use of molybdenum heating elements in air without danger of oxidation at temperatures up to 1650°C.

Another combined application of electronics and instrumentation is found in the plant of the x-ray division of General Electric Company in Milwaukee. The products of this plant include diffraction units for medical, dental, and industrial purposes, including equipment for recording the qualitative and quantitative analysis of materials, radiographic apparatus, Coolidge x-ray tubes, and electrocardiographic equipment. A number of other manufacturers in Chicago produce similar equipment.

The instrumentation included in this survey may involve electronic devices, electrolytic or other electrochemical phenomena, or the application of existing instruments to measurements of particular interest to electrochemists, electrometallurgists, and electronics engineers. Included are the measurement of *p*H, polarization, radioactivity, electrolytic conductivity and temperatures, the analysis of gases, liquids, and solids, spectometry, potentiometry, oscillography, differential thermal analysis, and electronic instrumentation.



© *Bill Hedrich, Hedrich-Blessing*

FIG. 5. Slow neutron irradiation tank and scaler rack used for nondestructive nuclear measurement of radar waveguide silver-plate thickness at the Armour Research Foundation, Chicago. The entire experiment is recorded by automatic wide-range radiation detector on the table at the right.

The Crerar Library states that, as of 1952, there were 81 industrial laboratories of the Chicago metropolitan area concerned with research in scientific apparatus. About one-fourth of these appear to be concerned with carrying on research in, and manufacturing apparatus of the type enumerated in the previous paragraph. In addition, there are a number located outside the metropolitan area, particularly in Milwaukee, Rockford, and Michigan City. Included in this category, in addition to those companies previously mentioned, are: Gaertner Scientific Corporation; Precision Scientific Company; Central Scientific Company; E. H. Sargent and Company; Coleman Instruments, Inc.; GM Laboratories, Inc.; Simpson Electric Company (Division of American Gage & Machine Company); and Wheelco Instruments Division of Barber-Colman Company in Rockford.

Of interest to electrochemists are the products of Coleman Instruments, Inc., of Maywood (surburb of Chicago) primarily engaged in the manufacture of analytical tools for the laboratory chemist. Foremost among these tools, of particular interest in the electrochemical field, are the glass electrode *p*H meters, a class of instruments in which this company has pioneered since Coleman introduced the first successful commercial instrument in the early 1930's. This company also makes diffraction grating spectrophotometers and, more recently, has developed and is making two models of photonephelometers.

Education and Research

The excellent educational facilities of this region include the University of Chicago, Illinois Institute of Technology, Northwestern University, Chicago branches of the University of Illinois, DePaul University, and Loyola University, all in Chicago and suburban Evanston, and Marquette University in Milwaukee. However, four important centers of education and research, which have much influence on this region, are located just beyond its defined borders. These are the Universities of Wisconsin, Illinois, Notre Dame, and Purdue.

The research work done at the above educational institutions is supplemented by that done or sponsored by the Wisconsin Alumni Research Foundation at the University of Wisconsin, the University of Illinois Foundation, and the Armour Research Foundation on the campus of the Illinois Institute of Technology in Chicago. During the 1951-52 fiscal year, Armour's staff, working on nearly 400 projects, achieved a research volume exceeding $8,000,000.

The Argonne National Laboratory is located a short distance west of Chicago. The impact of the research and other work being done here is world-wide and much of it is of particular interest to electrochemists.

The services of a considerable number of private research laboratories are also available to the public. The Crerar Library estimated in 1952 that approximately 10 per cent of all research laboratories in the United States, more than 230, are maintained in the Chicago metropolitan area by industry, schools, and government, and that nearly $290,000,000 would be spent in 1952 for research alone. Following is the Library's listing of the number of industrial laboratories doing research work in each of a number of fields of industrial activity: 60 in metals, 48 in minerals, 27 in petroleum, 85 in pharmaceuticals, 133 in chemicals, 26 in building materials, 55 in communications, 40 in electrical machinery, 81 in food, 61 in machinery, 81 in scientific apparatus, 8 in textiles, 31 in wood products, and 50 in transportation equipment. Although the number of research laboratories is given as 230, the National Research Council reports over 1200 industrial laboratories of all types in this metropolitan area.

The John Crerar Library is a valuable asset to the scientific world and particularly to scientists of this region. It has been in existence for over half a century and today is the largest library in the United States devoted to the fields of science, technology, and medicine. All collections are available for use without charge. The value of the Crerar Library is enhanced by the closely adjacent and very extensive patent library of the Chicago Public Library, an across-the-street neighbor.

Another type of library is maintained and directed by the Armour Research Foundation—the National Registry of Rare Chemicals which was established in 1942. It serves scientists all over the world as a central clearing house of information on the availability of chemicals not stocked by supply houses. Chemicals are not bought, sold, or stocked, only a file being kept of their availability. The registry's services are free. The file, grown to include over 25,000 com-

pounds is now virtually a national survey of existing supplies of rare chemicals.

Chemicals and Pharmaceuticals

The chemical industry of the Milwaukee-Chicago-Gary region is characterized by the wide diversity of its products and, further, it reflects the importance of the Midwest agricultural economy. The plant and animal products of this vast and rich agricultural area are the raw materials for an important part of this region's chemical industry, and, in turn, the chemical industry's products and by-products are used in important amounts on the farms that supply it with raw materials. The corn, soya beans, flaxseed, oats, barley, and other grains and vegetables are processed to yield such primary products as starch, glucose, corn oil, linseed and soya bean oils, protein products, and a variety of chemicals. Some of these primary products are processed further into many other chemical and allied products such as syrups, paints, margarine, glues, and plastics.

From the large packing industry of Chicago and Milwaukee come a variety of chemical and pharmaceutical products; in fact, it is often stated that it is this part of the business which is responsible for profits, if any. The growing list of chemical products varies over a wide range, including an appreciable number of recently developed or isolated chemicals and rare pharmaceuticals such as ACTH. Also, the large supply of hides was primarily responsible for the extensive leather-producing and using industries of the region; the large production of tallow and fats was the basis of the region's soap-manufacturing industry. The soap industry in turn produced a valuable chemical by-product, glycerine.

A third important agricultural product of the Midwest, milk, has not entered into chemical manufacture appreciably in this country. On the other hand, the chemical industry, particularly in this region, has become a serious threat to the dairy industry because of its large and rapidly increasing production of cheap margarine from animal and vegetable fats.

The McGraw-Hill Census of Manufacturing Plants for 1950 shows that 22.63 per cent of the plants of the chemical process industries in this country and 27.25 per cent of the employees are located in the North Central States (Ohio, Illinois, Michigan, Indiana, and Wisconsin). This area is a close second to the Middle Atlantic, New York, New Jersey, and Pennsylvania. The region also was second in chemical plant expansion in 1952 as reported by the Manufacturing Chemists Association, with the west south-central region in the lead. The 1947 Census of Manufactures credited the Chicago metropolitan area with 687 plants and 37,807 employees engaged in the manufacture of "chemicals and allied products." The value added by manufacture amounted to $385,123,000. In addition there were 80 petroleum and coal-products plants, of which 11 were refineries and 10 included by-product coke ovens, employing 23,327, and adding $181,044,000 of value through the manufacturing processes. Milwaukee is credited in the 1947 census with 119 establishments engaged in making chemicals and allied products, with 2909 employees, the value added by manufacture being given as $21,110,000.

Chemical production in this region includes at least 18 different chemical process industries. The most important of these are paint and varnish, soap and glycerine, industrial chemicals, drugs, perfumes and cosmetics, insecticides, and printing inks. In addition, the by-product coke ovens at the steel mills make important contributions to the production of organic chemicals from the by-product coal tar.

Closely related and sometimes overlapping the chemical industry are the food, leather-producing, and petroleum-refining industries, all of which are extensive, particularly the food, which includes the well-known large brewing establishments in Milwaukee.

The close-in consuming market for the chemical producers of this region are industries such as the leather, iron and steel, printing and publishing, general manufacturing, chemical household specialties, and the fast-growing plastics business. Beyond this area and within a radius of several hundred miles are such consumers of chemicals as the pulp and paper producers in Wisconsin, the automobile manufacturers in Michigan, the glass and rubber manufacturers in Ohio, and the farming areas extending throughout the midwestern states where fertilizers, fungicides, insecticides, herbicides, and other agricultural chemicals are consumed.

Sulfuric acid, often considered to be the most important basic chemical, is being made in 18 plants located within a 100-mile radius of Chicago. The production exceeds one million tons. In addition to the acid produced by the government at its Joliet Arsenal (Elwood and Kankakee ordnance plant and works), acid is being produced at plants operated by the following companies: Armour Fertilizer Works; Wilson & Company; Swift & Company; E. I. du Pont de Nemours & Company; Mathieson & Hegeler Zinc Company; American Cyanamid Corporation; Blockson Chemical Company; Allied Chemical & Dye Corporation; Standard Oil Company of Indiana; Stauffer Chemical Company; and Smith-Douglass Company. Blockson has three plants in operation and is building a fourth at Joliet.

Heavy chemicals, other than sulfuric acid, are produced by a number of manufacturers, including American Cyanamid Company, E. I. du Pont de Nemours & Company, Allied Chemical & Dye Corporation, Wilson & Company, Armour & Company, Diamond Alkali Company, Philadelphia Quartz Company (in Utica, Illinois), Victor Chemical Works, and Blockson Chemical Company. Although International Minerals & Chemical Corporation operates only a fertilizer acidulating and mixing plant in this region (in Chicago Heights), its research laboratories are located in Skokie, a Chicago suburb.

Special mention is being made of the phosphate chemical industry because two of the country's five major producers of sodium phosphates are located in the Chicago area. The industry had its inception in this region in 1897 when August Kochs started making monocalcium phosphate for use in baking powder. This operation in Chicago Heights was the beginning of the Victor Chemical Works, now one of the leading producers of a line of phosphate chemicals and products incorporating them. Another large producer of chemical phosphates and fluorides, as well as phosphate fertilizer, is the Blockson Chemical Company of Joilet, Illinois, producer of 20 per cent of the nation's total sodium phosphate output. This operation is of special interest because of the recovery of the uranium present in the rock phosphate ore used.

Additional manufacturing establishments in the inorganic field include those of the National Aluminate Company in Chicago and the Dearborn Chemical Company in Joilet, both producers of water-treatment chemicals (and also ion-exchange resins); the Joilet plant of the Eagle Chemical Company for making silica gel; the petroleum catalyst plant of American Cyanamid Company in Michigan City, Indiana; and that of the Lindsay Chemical Company at West Chicago, Illinois, where there is produced 85 per cent of all the industrially used so-called rare earths. In this plant the raw materials, such as monazite and the recently discovered Cali-

fornia bastnasite ore, are treated to separate and purify certain of the rare earth elements contained in them. The elements include cerium, thorium, yttrium, lanthanum, didymium, gadolinium, samarium, neodymium, and praseodymium. A $1,800,000 expansion program to be completed by autumn of 1953 involves an increase in the production of thorium nitrate for defense use (7).

The organic chemical industry is diverse in this region. It includes the production of petrochemicals, organics made from other raw materials and especially those derived from agriculture, and the production of pharmaceuticals.

Petrochemicals are made by a number of the petroleum refining companies and by others that utilize the products and by-products of refineries as described in the next several paragraphs.

At the Whiting, Indiana, refinery of the Standard Oil Company of Indiana, the following petrochemical operations are being carried on: 55 tons of sulfur are being recovered daily from refinery gas; the plant's capacity for making benzene is now 16,000,000 gallons per year; alkymer, a base stock in synthetic detergents, is being made from this benzene and a propylene tetramer manufactured at a southern refinery; alkanesulfonic acid is being made. A subsidiary, Indoil Chemical Company, markets some of these products.

Union Carbide and Carbon Corporation at its Whiting, Indiana, plant uses oil-refinery gases in its operations. This plant produces acetic anhydride, acetone, methyl isobutyl ketone alcohols, and ethylene glycol. Continental Oil Company produces detergents at its Chicago plant by the sulfonation of petrochemicals made at its Baltimore plant. Velsicol Corporation in Chicago makes hard resins and synthetic insecticides from petroleum-based raw materials.

The following companies, interested in the refining of petroleum, maintain research laboratories in the Chicago metropolitan area in which petrochemical research is carried on: Anderson-Prichard Oil Corporation; Pure Oil Company; Sinclair Refining Company; Standard Oil Company of Indiana; and Universal Oil Products Company.

Other organic chemical producing plants in this region with their operators and products are: Spencer Chemical Company, formaldehyde and hexamine at Calumet City, Illinois; Edwal Laboratories, Inc., at Ringwood, Illinois, fine organics for the chemical-process industries such as intermediates for dyestuffs and drugs, flavoring materials, and new cyclic intermediates; Acme Resin Corporation of Chicago, Catalin Corporation of America, Calumet City, National Casein Company in Chicago, and Union Carbide and Carbon Corporation in Ottawa, Illinois, resins; Visking Corporation, Chicago, regenerated cellulose (from Viscose) films, particularly in the form of sausage casings; Carus Chemical Company, LaSalle, Illinois, hydroquinone and sodium benzoate; E. I. du Pont de Nemours & Company, East Chicago, Indiana, the chlorofluoromethanes marketed as the Freons used in refrigerating systems; The Emulsol Corporation, Chicago, surface-active materials; Ultra Chemical Works, Inc., Joliet, detergents; Sherwin-Williams Company, Chicago, paracresol; Victor Chemical Works, Joliet, formic and oxalic acids; the Barrett Division of Allied Chemical & Dye Corporation was scheduled to produce phthalic anhydride in a new $4,200,000 plant beginning in May 1953.

Koppers Company, the Barrett Division of Allied Chemical & Dye Corporation, and Reilly Tar & Chemical Corporation process coal tar into various materials for roofing purposes and for treating railroad ties, for paving tar and protective paints and other coal-tar products and chemicals.

An important chemical industry based on an agricultural product is that in which corn is processed by grinding and refining. The principal primary products, sold largely in bulk form, are starch, (corn) syrup, (corn) sugar, (corn) oil, and cattle and chicken feeds. The first four are also sold extensively in small packages, the syrup in the form of corn syrup and the corn oil for salad and cooking purposes. An important by-product is zein. Modified starch products and fine chemicals and pharmaceuticals, such as methyl glucoside, glucuronolactone, glucuronic acid, and inositol, also are produced. Among the several corn-processing plants in this region, the largest and best-known is that of the Corn Products Refining Company which built, in 1947, a $5 million food research laboratory at its Argo (Chicago suburb) plant.

In recent years the oil-containing soya bean has become a most important raw material and is now one of the principal crops in Illinois. As with the flax and cotton seeds, the protein-rich residue, after oil extraction, is used largely as a cattle food. Because the soya oil resembles linseed oil it is used for many of the same purposes. The Glidden Company, through its Soya Products Division in Chicago, has been very active in utilizing the bean and particularly the oil. The oil is used in the formulation of paints and in the preparation of food products such as margarine and shortenings. It is a raw material for resins. The soya bean also yields lecithin, pharmaceuticals, and protein flour and meals. The packing companies have been interested in the soya bean products.

The paint and varnish industry is well represented in this region. The 1947 Census of Manufactures listed 132 establishments in the Chicago metropolitan area and 13 in Milwaukee county which were engaged in making paints, varnishes, and lacquers. Included among the manufacturers that operate paint and varnish plants are: Sherwin-Williams Company; Glidden Company; Standard Varnish Works; Zapon Division of Atlas Powder Company; Standard-Toch Chemicals, Inc.; E. I. du Pont de Nemours & Company; Armstrong Paint & Varnish Company (established in 1854); Hooker Glass & Manufacturing Company (established in 1855); National Chemical & Manufacturing Company; Interchemical Corporation; Eagle-Picher Company; Pittsburgh Plate Glass Company (Milwaukee); and Solar Corporation (Milwaukee).

The large amount of fats produced by the packing industry in Chicago and Milwaukee was the foundation of a long-established large soap and glycerine industry and a more recently established chemical industry. Although a statistical breakdown is not available, Chicago is stated to be one of the three most important soap-production centers in the country, the other two being Cincinnati, Ohio, and the New York City-New Jersey area. The product value is estimated at $100,000,000 yearly. In addition to the four packing companies, Armour & Company, Swift and Company, Wilson & Company, and The Cudahy Packing Company, the well-known Proctor and Gamble Company, Allen B. Wrisley Company, and Lever Brothers have large soap-making plants in the metropolitan Chicago area. In recent years, synthetic detergents have made serious inroads on soap manufacture, and now their production is an important part of the output of soap manufacturers.

The packers, through research, are attempting to offset the declining market for both the edible and inedible fats produced by the packing operations. The problem is being attacked in several ways. One method is to follow the example set in the hydrogenation of cottonseed and other oils, that is, modify the various fats, such as tallow, greases, and lard, by hydrogenation or other means to make a product which has a market at a profitable price. Another attack is to separate the various constituents of the fatty acids derived from these

fats, which usually are a complex mixture, and market either the constituent fatty acids in purified form, or as fatty acid derivatives with definite properties and having well-defined uses. As an example of the latter approach, the Armour Chemical Division is now marketing purified fatty acids and a series of products derived from them. The Armour research, however, is not limited to animal fats and the products may be derived from any suitable fat source, including the vegetable oils. Quaternary ammonium salts of these fatty acids are being marketed. Recently produced are the higher molecular weight ketones based on the stearic, lauric, and palmitic fatty acids. Other compounds of these fatty acids are being marketed as emulsifiers for wax formulations, and stabilizers for vinyl films.

Early in 1953 the Stepan Chemical Company, producer of a liquid anionic detergent, started up a semi-works plant for making 1,500,000 lb a year of fatty alcohols by a sodium reduction process from tallow, which has been a drug on the market recently. These may also be made from other fats and oils. At about the same time patents were issued to Swift & Company for catalytic agents for use in modifying lard to make it more like hydrogenated vegetable oils, such as are being sold for cooking purposes. Products of this type are now on the market.

Two of the largest manufacturers of pharmaceuticals in this country, Abbott Laboratories and Armour & Company, lead the drug and pharmaceutical industry in the Milwaukee-Chicago-Gary region. In contrast to the founding of the Abbott enterprise in 1888 when Dr. Abbott started to make certain drugs which were difficult to obtain, Armour & Company, meat packers, were pioneers in that branch of the pharmaceutical industry, which was an outgrowth of meat packing, whereby glandular by-products of the slaughter house were used in human therapy. The most recent addition to the Armour facilities in this field is a $12,000,000 plant in Bradley, Illinois, about 50 miles south of Chicago. This was scheduled to go into operation in May 1953. About 20 per cent of the plant, known as the Armour Pharmaceutical Center, is to be used for making from whole blood the gamma globulin which is useful for fighting polio. The balance of the plant is to make ACTH, insulin, thyroid extract, trypsin, and other biological products obtained from animals slaughtered for meat packing. Wilson & Company, Inc., similarly makes pharmaceuticals.

Of particular interest among the approximately 1000 listed items which are produced by Abbott Laboratories at North Chicago, Illinois, are the new radioactive pharmaceuticals and cobalt-60 needles.

In another by-product utilization operation, Pabst Brewing Company of Milwaukee is producing chemicals and pharmaceuticals from the by-products of the brewing industry. In 1951 the company began making vitamins for use in livestock feed. The vitamin B-2 and the antibiotic, bacitramin, used in livestock feed, are produced. In addition, five chemicals are being made from yeast. Enzymes and coenzymes are also being produced. Malt syrups are made for the food, pharmaceutical, and textile trades.

G. D. Searle & Company of Skokie (Chicago suburb) also is an important producer of pharmaceuticals.

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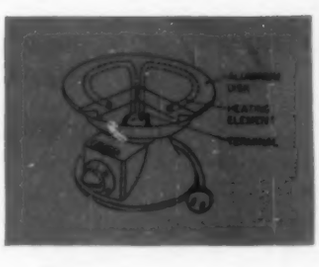

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The Mechanism of Electropolishing of Copper in Phosphoric Acid Solutions

II. The Mechanism of Smoothing

J. Edwards[1]

ABSTRACT

Experiments with a composite anode having projections and recesses on its surface insulated from each other showed that the current distribution between projections and recesses underwent very little change when the total current fell and polishing conditions were established. This called for a radical revision of previous views of electropolishing, and prompted a quantitative investigation of the smoothing efficiency under different conditions on a surface of standard roughness. The observed efficiencies were compared with those calculated for a wholly diffusion-controlled distribution of attack (identical with primary current distribution) and for equal dissolution at all points on the surface. The conclusion reached is that the mode of smoothing in electrolytic (and chemical) polishing is not specific to these processes, but results solely from the variations in concentration gradient within the diffusion layer set up on the anode surface. For any surface of known shape there is, therefore, a maximum possible smoothing efficiency.

Introduction

The various theories of electropolishing suggested in the past explain the preferential dissolution of raised areas of the anode in terms of the properties of the layer of electrolyte in immediate contact with the anode. The procedure in most cases has been to determine certain properties of this layer, directly or indirectly, and then to consider the likely effect of unevenness in the surface and whether the observed properties could contribute to a leveling effect. It seemed, however, that the way in which smoothing actually occurs could only be determined by a study of the contrasting behavior in a polishing solution of peaks and recesses on the anode surface. Such a study is described in Section 1, below. Quantitative experiments on the rate of smoothing of a standard surface undertaken to confirm the views formed are dealt with in Section 2.

1. Qualitative Study of Smoothing Action

The intensity of the smoothing action during electropolishing depends on the current density (and thus the rate of removal of metal) on projections and in recesses. If the surface of recesses becomes passive, as was suggested by Evans (1), there should be a rapid increase in the ratio of current densities on projecting and recessed surfaces as the transition from anodic etching to anodic polishing takes place; if Jacquet's view (2) is correct, a more gradual increase in the ratio should occur. To provide evidence on this point, a laminated anode was constructed and used as described below.

Experimental

Construction of Laminated Anode

Copper sheet (0.1 mm thick) and mica (approximately 0.015 mm thick) were cut into pieces of the shapes shown in Fig. 1. "Redux" adhesive was applied to the surfaces after cleaning and roughening them slightly. Thirty-six pieces of copper, interleaved with mica, were assembled with their tags on each side, alternately, in a specially designed press, the adhesive being then cured at 160°–170°C under pressure. A wire was soldered on to each set of tags. The anode was then set in a cold-setting resin, up to three-quarters of its length, leaving the tags free. A glass holder was made and the anode fitted and sealed in, as shown in Fig. 2. The top of the anode was then abraded on a fine glass-paper under white spirit in a direction parallel to the laminations.

Use of Laminated Anode

The anode was first tested in a polishing cell to confirm that the two sets of laminations behaved alike—as they should while the surface is flat. Alternate layers of copper were then polished back by making this set the anode in a cell containing 50 per cent by volume phosphoric acid. After rinsing and drying, the excess adhesive was cut away, under a binocular microscope, from the sides of the projecting copper laminations to the level of the recessed set.

The circuit used for experiments with this anode is shown in Fig. 3. P is a low resistance (1 Ω) potentiometer. The current through each portion of the anode is measured by recording on a cathode ray oscillograph the voltage drop across the two small variable resistances, S_1 and S_2. The cell was that shown in Fig. 3 of Part I* of this paper, without the glass shield however, the laminated anode replacing the one shown. The electrolyte in all experiments described was 50 per cent by volume *o*-phosphoric acid at 25°C.

All oscillographs were printed with a fixed enlargement ratio and calibration scales used to derive from the prints the continuous current-time curves which are reproduced here.

Results

In a preliminary experiment with the two sets of copper leaves at the same level and the same voltage applied to them, it was found that the currents flowing through the two sets were equal and that the laminations did not prevent the normal attainment of polishing conditions.

[1] British Non-Ferrous Metals Research Association, London, England.

* July 1953 JOURNAL, page 189C.

With one set of leaves dissolved back electrolytically to an average depth of 0.15 mm and with $S_1 = S_2 = 5\ \Omega$, the currents through the two sets of leaves were found to oscillate in opposite phase. This was shown to be due to the difference in potential between the two sets of leaves, produced by a larger current flowing through the projecting set than through

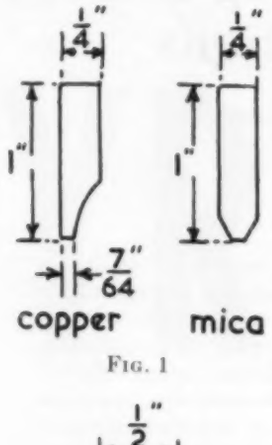

FIG. 1

FIG. 2. Laminated anode

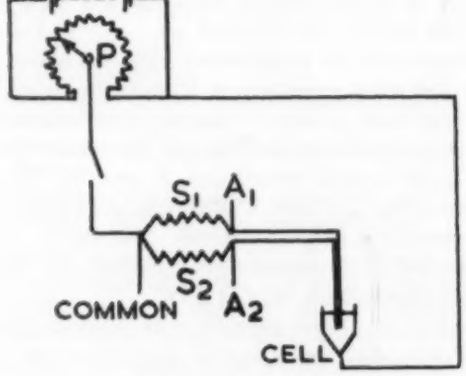

FIG. 3. Circ.

the recessed set, via resistances of the same value. To overcome the difficulty, the values of the resistances S_1 and S_2 were adjusted until (*a*) the oscillograph deflections for both halves of the anode just after applying current were the same, and (*b*) both S_1 and S_2 were as low as they could be made, consistent with a reasonable screen deflection on the cathode ray oscillograph when using the amplifiers at maximum sensitivity. It was found that only one ratio of resistance values S_1/S_2 was required to maintain equality of the anode potential

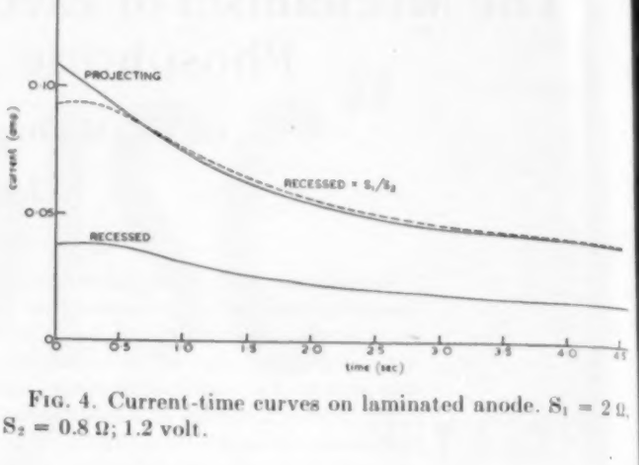

FIG. 4. Current-time curves on laminated anode. $S_1 = 2\ \Omega$, $S_2 = 0.8\ \Omega$; 1.2 volt.

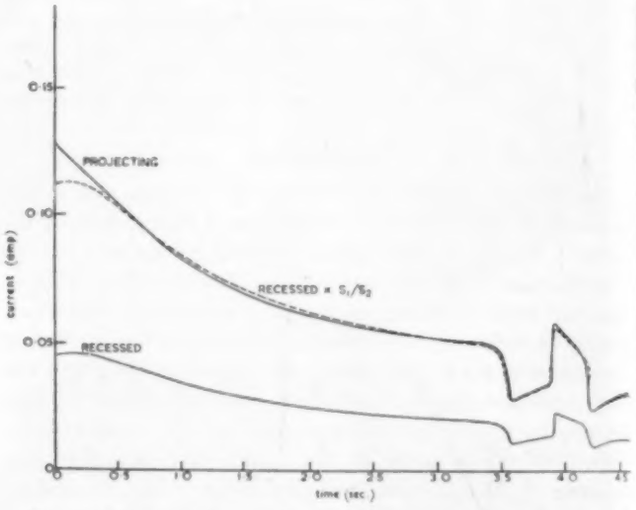

FIG. 5. Current-time curves on laminated anode. $S_1 = 2\ \Omega$, $S_2 = 0.8\ \Omega$; 1.4 volt.

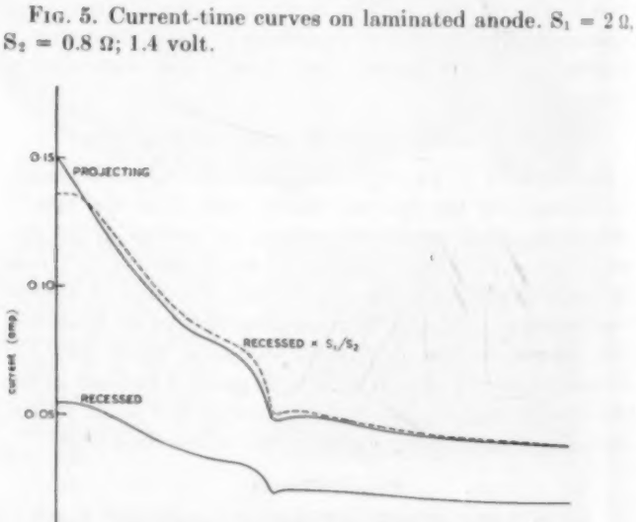

FIG. 6. Current-time curves on laminated anode. $S_1 = 2\ \Omega$, $S_2 = 0.8\ \Omega$; 1.6 volt.

at all times (while the anode surface retained the same shape). The curves in Fig. 4, 5, and 6 show the variation with time of the current through the recessed and projecting leaves

hen open-circuit voltages of 1.2, 1.4, and 1.6 volts, respectively, were applied across the cell. The resistances in the eds of the recessed and projecting leaves were 2.0 and 0.8 , respectively. The broken lines, giving the current through e recesses multiplied by $S_1/S_2 = 2.5$, show clearly the aintenance of the current ratio and also of potential equalty. Such differences as occur are in the direction correspondg to a reduction, not an increase, in the preferential dissolun of the projections.

Discussion

The above experiments show that on a rough surface of niform potential the current density on projecting areas is reater than on recessed, but that the ratio does not change ignificantly on passing from etching to polishing conditions. his calls for a radical revision of previous views of the moothing mechanism which have assumed that the preferenial dissolution effect is brought into action at this point. In ct, no such preferential action specific to electropolishing an now be maintained.

According to the acceptor hypothesis proposed in Part I, he rate of dissolution of metal from an anode which is being lectropolished is determined by the rate of arrival at its urface of acceptor ions or molecules. These are brought up o the surface by diffusion and convection but, since the oncentration gradient is as steep as is possible, the contribuion of convection will be small and can, for the moment, be eglected. Therefore, a steady state exists in which the relative rate of dissolution at any point on an irregular surface is etermined solely by the geometrical form of the surface. his is the case whatever the nature of the ions or molecules hose concentration gradient controls metal dissolution.

Since the laws of diffusion and of electrical intensity are of dentical form, the system corresponds to the electrostatic ase of an isolated charged surface, planes of equal concentration in the former coinciding with equipotential planes in the latter. This was pointed out by Elmore (3) although he believed the concentration gradient of dissolved metal ions to be the controlling factor. However, the current distribution on an unpolarized or ideally polarized electrode (the primary urrent distribution) corresponds to the same model. This explains why there is little difference between the current distribution immediately after application of the voltage and that under polishing conditions.

The experimental results indicate further that this distribution remains substantially constant throughout the whole of the period preceding the establishment of polishing conditions, presumably because those points which are able to receive a high current in the first instance are in a similarly favorable position with respect to diffusion to or from the surface. Thus, although the rate of dissolution varies over the surface during the establishment of the steady state, the concentration at the surface of each ion or molecule taking part in the electrode process remains approximately uniform, varying at the same rate at all points. This explanation is confirmed by the experimental fact that the sharp fall in current occurred at the same time on peaks and recesses so long as they were at the same potential.

A quantitative study of the extent of smoothing on a surface of known shape was undertaken at this stage in order to confirm that the soothing efficiency approaches that corresponding to the primary current distribution or to a wholly diffusion-controlled process. Section 2 deals with this work.

2. Quantitative Study of Smoothing Action

For a given initial surface, the smoothing efficiency may be defined as the reduction in roughness (expressed in terms of a suitable parameter) which accompanies the removal of a given amount of metal per unit area. The surfaces used in this work were of copper, electroformed on a plain-cut microgroove gramophone-record matrix and on its negative. Two parameters were chosen to represent the degree of roughness: average height and maximum height above the bottom of the grooves. These were measured on sections of the surfaces enlarged photographically to ×1000, the average height being obtained by measuring the area above the lowest points with a planimeter and dividing by the length of the base $\times 10^3$.

In two sections following are described the computation of smoothing efficiences for certain hypothetical conditions at the anode surface, and the determination of actual smoothing efficiencies under different experimental conditions.

Computation of Limiting Smoothing Efficiencies

According to the evidence of Section 1, the greatest possible rate of smoothing is that corresponding to the primary current distribution. This distribution for a given surface can be determined by constructing a diagram of equipotential and current lines; the two sets of lines are drawn so that they

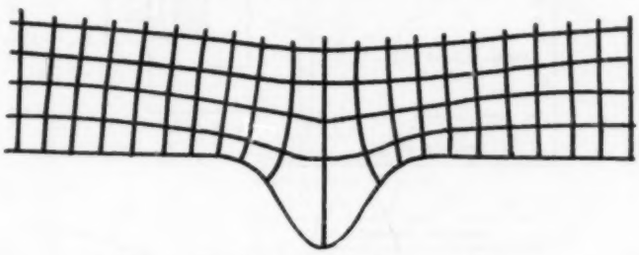

FIG. 7. Equipotential and current lines

FIG. 8. Successive stages of dissolution

intersect everywhere at right angles forming quadrilaterals which approach the shape of squares as closely as possible, i.e., the sums of opposite sides should be equal. In the resulting lattice, the current flowing between adjacent current lines and the potential differences between adjacent equipotential lines are each constant. A roughly drawn example showing the current distribution on an infinite plane surface having a single groove is given in Fig. 7. The position of the equipotential lines can be determined directly by experiment on an enlarged replica of the surface; the technique of doing so is described later.

On a surface such as that shown in Fig. 7, the smoothing corresponding to primary current distribution will produce successive surfaces something like those in Fig. 8. Assume that the contours in this diagram represent the state of the surface at successive stages of dissolution, a constant amount of metal being removed, or a constant time elapsing between each stage (if the total current is constant). Another set of lines (Fig. 9), constructed so as to cut the first always at right angles, represents the direction of dissolution, since dissolution proceeds perpendicularly to the surface. If the lines are so spaced that the distance between them measured along the surface is proportional to the local current density, they will cut the first set so as to form quadrilaterals all over the dia-

gram in each of which the mean dimensions in the two directions will be equal, provided the correct units are chosen, since the depth dissolved per unit time is proportional to the current density. The two sets of lines thus form an orthogonal lattice of the type referred to above which has a unique form for a given limiting surface. It is the same, therefore, as the

FIG. 9. Dissolution stages and dissolution lines

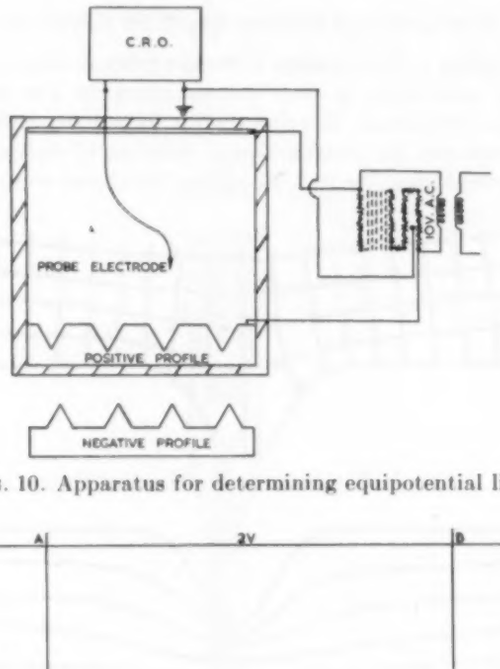

FIG. 10. Apparatus for determining equipotential lines

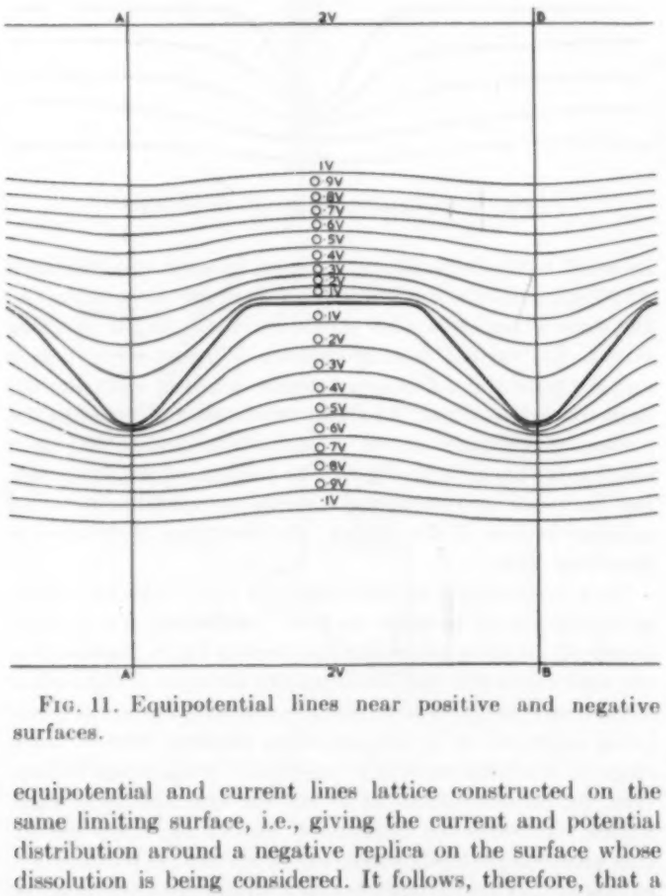

FIG. 11. Equipotential lines near positive and negative surfaces.

equipotential and current lines lattice constructed on the same limiting surface, i.e., giving the current and potential distribution around a negative replica on the surface whose dissolution is being considered. It follows, therefore, that a chart showing the surface of an anode at successive stages of dissolution under primary current distribution can be obtained by plotting the equipotential lines between the negative of that surface and a distant electrode.

In an orthogonal lattice bounded by an electrode surface the distance between adjacent lines perpendicular to the surface has been interpreted as the measure both of the current density on one side of the surface and of the inverse (area/unit current) on the other. It follows, therefore, that the primary current density at a given point on the surface is inversely proportional to that at the corresponding point on the negative replica of the surface. This can be checked experimentally.

In practice, the concentration gradients in the neighborhood of the anode are unlikely to correspond exactly to the electrostatic model. On very sharp irregularities, the size and inertia of the ions may prevent the attainment of ideal conditions, and the influence of convection will also be considerable in some cases. Current distribution might therefore tend to the other limit of equal current density over the whole surface, there being a greater degree of polarization on peaks than on recesses. Under these conditions the minimum possible smoothing efficiency would be obtained, provided that the current efficiency remained constant. Some smoothing would occur, however, since the attack on the sides of the asperities would reduce their area and, subsequently, their height.

Experimental and Results

The apparatus for locating equipotential lines near a given electrode surface is shown in Fig. 10. The tray, 2 ft x 2 ft x 1 in., was made of ebonite. The shape of each surface to be investigated (the profiles of the microgroove positive and negative, enlarged 1000 times) was cut out of a block of paraffin wax 2 ft x 4 in. x ¾ in., and a ¾-in. strip of silver-plated copper foil was stuck to this shaped edge. The other electrode was a silver-plated bar of copper. Sliding along two steel scales fixed on opposite edges of the tray was a further scale screwed on to a supporting tube and carrying the probe electrode. This could be moved along the tube and its position accurately determined by reference to the scales. The probe was of platinum wire sealed in a glass tube with a mercury contact and projecting ⅛ in. The tray was filled to a depth of ½ in. with tap water. Equipotential lines were determined by applying 10-volt a.c., selecting the required potential on the 100 point, 100 Ω potentiometer in parallel with the tray, and then moving the probe electrode so as to get the minimum signal on the cathode ray oscillograph. Points were plotted at intervals along the parallel scales.

The curves obtained are shown in Fig. 11. The distance of a chosen equipotential line from the original surface (measured orthogonally) is approximately inversely proportional to the distance to the corresponding line on the other side. Since this distance is inversely proportional to the current density, the result agrees with the conclusion reached above that the primary current density at a given point on a surface should be inversely proportional to that at the corresponding point on the negative replica. This may be taken as confirming the view that these equipotential lines also represent stages in dissolution of the surfaces. Thus the maximum possible smoothing efficiency on the positive surface can be calculated from the equipotential lines near the negative and vice versa.

In that part of the diagram between the lines of symmetry *AA* and *BB*, the area enclosed between successive lines is constant and corresponds to the removal of 4.77 mg of copper per cm² for both the positive and negative surfaces. Values of the average and maximum height parameters measured

in Fig. 11 are plotted as A_1 and A_2, respectively, in Fig. 12 and 13 and subsequent illustrations.

The surface contours corresponding to equal dissolution at all points were obtained by construction. The values of the roughness parameters after removal of given amounts of metal were derived from the resulting diagram as before, except that in this case it was necessary to measure the area between each line and the original surface, since this did not increase in equal steps as in Fig. 11. The results are plotted in Fig. 12 and 13 and subsequent illustrations as B_1 and B_2 for average height and maximum height, respectively.

Experimental Determination of Smoothing Efficiencies

In the first series of electropolishing experiments described below, convection and general movement of solution were kept as low as practicable, in an attempt to obtain the maximum smoothing efficiency. In later experiments, a study was made of the effect on smoothing efficiency of permitting increased convection, of stirring the electrolyte, and of modifying its viscosity. Since other workers have variously suggested that the best polishing occurs (*a*) when the current is oscillating rapidly (4), i.e., at the lower end of the voltage range, and (*b*) when the resistance of the cell is at a maximum (5), i.e., at the upper end of the range, smoothing experiments have been carried out under each of these conditions.

The smoothing efficiency of electropolishing depends, according to the suggested mechanism, on the relative contribution of diffusion and convection to the controlling electrode process. Therefore, in a given cell (in which convection is constant) the smoothing power should vary with the current. This was confirmed in a qualitative manner by examining two specimens from which the same amount of metal had been removed by electrolytically etching at widely different rates. It was not possible to carry out this experiment on electropolished anodes since the current is constant under polishing conditions.

It was suggested in Part I that the mechanism of "chemical polishing" might be dependent on the same factors as control electrolytic polishing, i.e., zero concentration of "acceptors" on the surface preventing etching, and a diffusion-controlled dissolution producing smoothing. With the vigorous agitation necessary in this process, it was not expected that the smoothing efficiency would be at the maximum, but it was felt that, if it could be shown to approach that value, the results would confirm this view of the process. A series of experiments was therefore carried out to determine the smoothing efficiency of a chemical polishing solution. Similar experiments were also made with a "bright dip" solution, which gives a bright but etched surface, since it was expected to provide a useful comparison with the chemical polish.

Experimental

Preparation and Examination of Specimens

Two electroformed copper sheets, approximately 1.5 mm thick with surfaces corresponding to a plain-cut microgroove gramophone record and its negative, were kindly supplied by the Decca Record Company. Small pieces sawed from these sheets were degreased and soldered on to the ends of ¼-in. diameter brass rods, the copper being then trimmed with a file and emery paper to the same size as the rod. Specimens prepared in this way were used for all the work described in this section. They were cleaned thoroughly and then weighed, except in the first series of experiments in which the amount of copper dissolved was determined by weighing the cathode of a series coulometer. This procedure was varied slightly in preparing specimens for the electrolytic etching experiments; to prevent errors due to the differing crystallographic structure between ridges and grooves on the electroformed surface, which is unimportant in electropolishing but would probably affect etching characteristics, the specimens, before mounting, were annealed for 15 min at 400°C in N_2.

After polishing, each specimen was reweighed and the small disk of copper detached by heating the rod. The disk was gripped in a small clamp with an aligned saw-cut and sectioned perpendicular to the grooves. Both halves were mounted in Bakelite and metallographically polished in the usual way. A typical portion of the profile was photographed at a magnification of 250. Prints were then taken with an enlargement ratio of 4, making a total magnification of 1000. The roughness parameters were determined from this photograph.

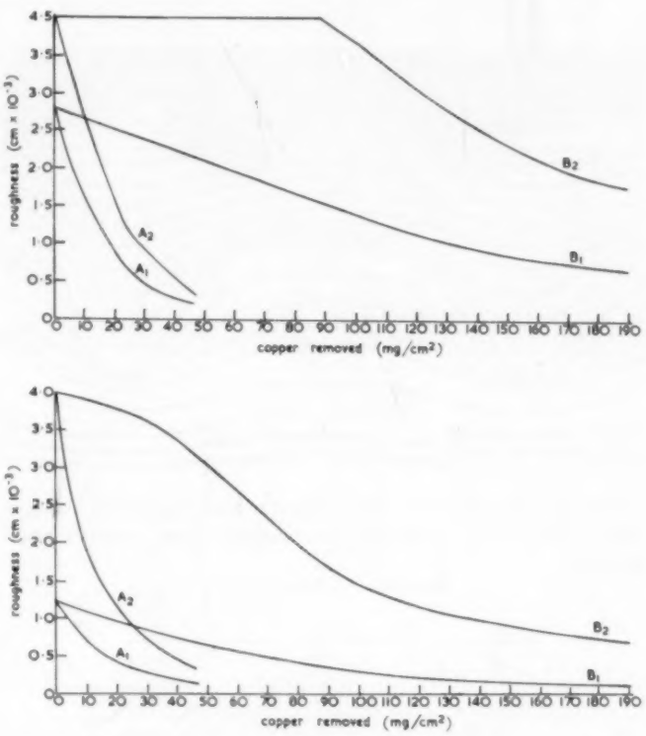

FIG. 12 AND 13. Theoretical smoothing efficiencies. Fig. 12. (*top*) Positive surface. Fig. 13. Negative surface. A_1—Average height, primary current distribution; A_2—maximum height, primary current distribution; B_1—average height, equal dissolution; B_2—maximum height, equal dissolution.

Polishing and Etching Methods

For electrolytic polishing and etching under conditions of minimum convection the cell was similar to that shown in Fig. 1, Part I, having a ½-in. high glass shield around the anode. To prevent the current falling to too low a value, the anode layer was stirred at 10-min intervals. A copper coulometer in series with the cell gave a measure of the quantity of electricity passed and, therefore, of the weight of copper dissolved from the anode.

The shield was removed from around the anode for the experiments in which convection was permitted, and, in order to obtain fairly uniform current distribution over the specimen, the arrangement shown in Fig. 14 was adopted. The specimen fitted closely into a solid dome of copper held in a shaped ebonite disk. The copper cathode was turned to the shape shown in the diagram. For the experiments in which the electrolyte was to be agitated, the cathode was fitted with

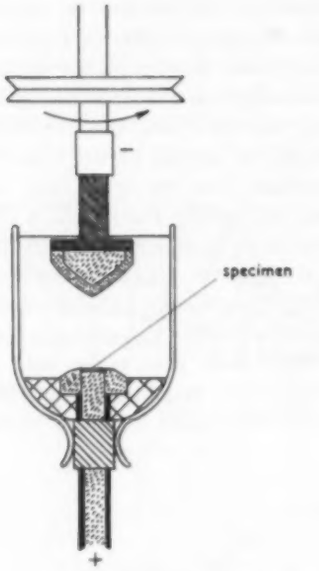

FIG. 14. Cell

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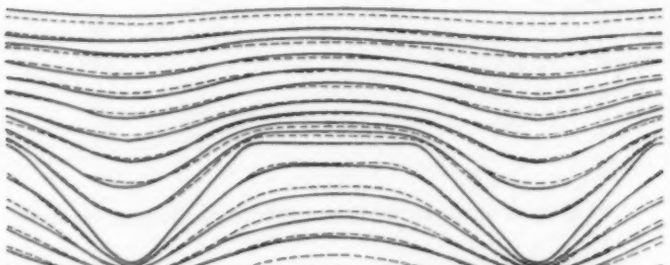

FIG. 15. Theoretical and experimental surfaces; broken lines, theoretical surfaces; continuous lines, experimental surfaces.

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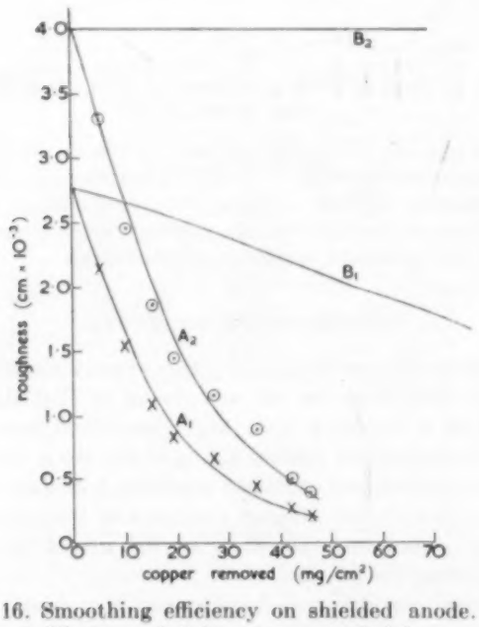

FIG. 16. Smoothing efficiency on shielded anode. Positive surface. ⊙, Maximum height; ×, average height.

a thin vane of copper sheet and itself used as the stirrer. Since the copper dome dissolved as well as the specimen, the copper lost by the anode was determined by direct weighing. Accurate control of the voltage within the polishing range was facilitated by including a cathode ray oscillograph in the circuit, arranged so as to show voltage variations horizontally and current variations vertically.

Current was obtained from a 4-volt accumulator applied across a low-resistance potentiometer.

In the experiments with a chemical polishing solution, the specimen, protected at the sides with rubber tubing, was agitated by clamping it through a hole in a pulley wheel which was rotated at the chosen speed. This method gave poor results when applied in a bright dip solution, so in this case a similar specimen was agitated by hand.

Results

Electropolishing of Shielded Anode

Shielded anodes, with surfaces corresponding to both positive and negative microgroove records, were electropolished in 50 per cent by volume *o*-phosphoric acid at 25°C. The surface profiles obtained are reproduced in Fig. 15, superimposed at the correct levels (estimated from loss in weight) on the series of theoretical surfaces (as in Fig. 11) correspond-

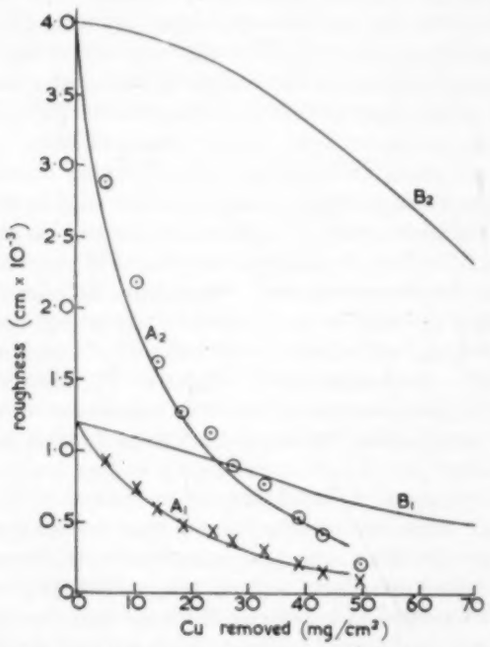

FIG. 17. Smoothing efficiency on shielded anode. Negative surface. ⊙, Maximum height; ×, average height.

ing to primary current distribution. The experimental surfaces are seen to conform closely to the theoretical. This is also evident in Fig. 16 and 17 which show the decrease in average height and maximum height against weight of metal removed per cm².

Thus, under the conditions of these experiments there is a nearly perfect diffusion layer in contact with the anode, so that the concentration gradients correspond to the potential gradients in the electrostatic case, and the smoothing efficiency is very close to the maximum.

Electropolishing of Unshielded Anode

Experiments were performed under the five sets of conditions listed below. The resulting values of the average height parameter are plotted in Fig. 18 against the weight of metal removed per cm². The maximum height values have a similar distribution which is, therefore, not shown.

1. Phosphoric acid—50 per cent, 25°C, low voltage. The voltage was adjusted to the lower end of the flat portion of the current-voltage curve as seen on the oscillograph. Current oscillations were maintained for most of the time.

2. Phosphoric acid—50 per cent, 25°C, high voltage. The voltage was adjusted to just below the upper end of the flat portion of the curve, i.e., just under the voltage at which gas would be evolved. Where the polishing was continued for a considerable time it was necessary to lower the voltage slightly, at intervals, to prevent the evolution of gas.

3. Phosphoric acid—50 per cent, 25°C, with stirring. The cathode fitted with the stirring vane was rotated at 60 rpm. Higher speeds were unsatisfactory since the solution became loaded with hydrogen bubbles from the cathode.

4. Phosphoric acid—50 per cent + glycerol, 25°C, no stirring. The viscosity of this solution was the same as that of a 75 per cent solution of phosphoric acid in water.

5. Phosphoric acid—75 per cent, 25°C, no stirring.

An intermediate voltage was used in conditions 3, 4, and 5. The graph shows that, in the absence of a hood, convection reduces the smoothing efficiency from its theoretical maxi-

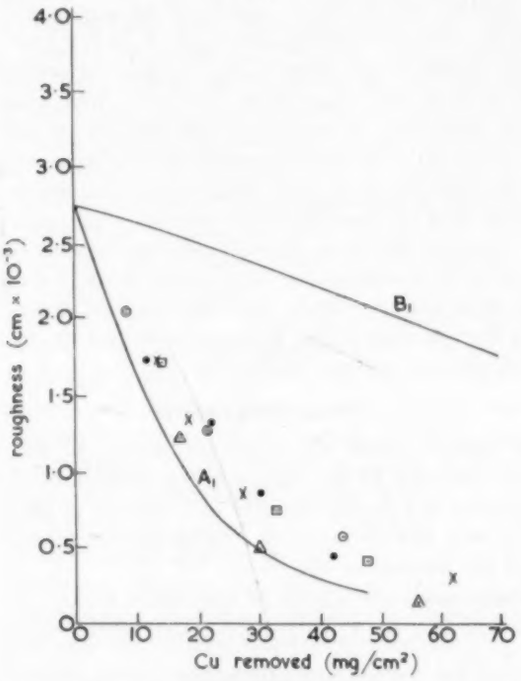

FIG. 18. Rate of smoothing of unshielded anode. Average height. ×—Low voltage, ⊙—high voltage, ●—stirred 60 rpm (50% phosphoric acid); △—50% phosphoric acid + glycerol, ⊡—75% phosphoric acid (same viscosity).

mum, although it is still far from the minimum value corresponding to equal dissolution at all points. Increasing the viscosity of the solution by the addition of glycerol appears to have restored the smoothing efficiency to the maximum, but the substitution of 75 per cent phosphoric acid (of the same viscosity as the 50 per cent phosphoric + glycerol) does not appear to have had the same effect. No change in smoothing efficiency was produced by voltage variation in the polishing range.

Thus, in practical conditions of electropolishing, a smoothing efficiency close to the maximum possible can be expected on irregularities which are small compared with those of the microgroove surface. Varying solution composition and the conditions of electrolysis would not produce any marked improvement in this factor.

Electrolytic Etching of Shielded Anode

The surfaces obtained by electrolytic etching are shown in Fig. 19a and b, corresponding respectively to the following conditions: (A) a current of 0.04 amp was applied intermittently for approximately 15 min; each time the current began to fall as polishing conditions were approached, the circuit was broken and the anode layer thoroughly stirred; (B) a

a

b

FIG. 19(a). High current etch; (b) low current etch.

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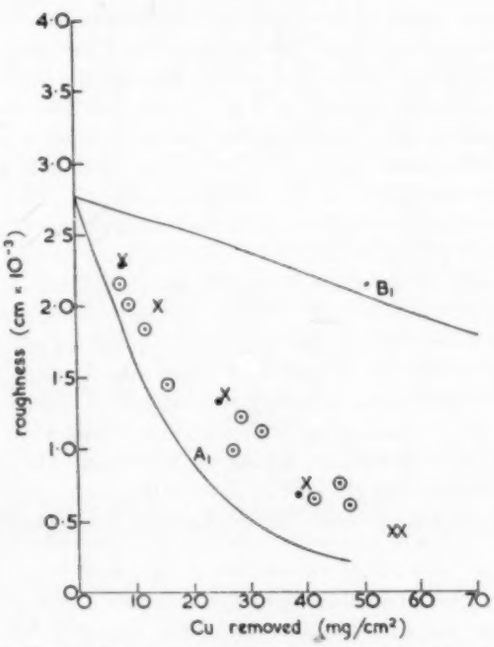

FIG. 20. Smoothing efficiency of chemical polish and bright dip. Average height. ⊙, Chemical polish 60 rpm; ×, chemical polish 120 rpm; ●, bright dip.

current of 0.0035 amp was maintained for approximately 90 min. In each case, 5.5 mg of copper was removed (17.5 mg/cm²).

The greater smoothing power at the higher current is clear from the photographs. It is also noticeable that while irregularities due to etching are prominent in Fig. 19b they can

scarcely be discerned in Fig. 19a, although polishing conditions were never fully attained in the latter case and the specimen had in fact a dull etched appearance.

Chemical Polish and Bright Dip

The values of the average height parameter plotted in Fig. 20 are for treatment at 80°C in a chemical polishing solution consisting of phosphoric acid—55 per cent, acetic acid—25 per cent, nitric acid—20 per cent, plus a small quantity (approximately 0.5%) of hydrochloric acid, and at room temperature in a bright dip solution containing sulfuric acid—40 per cent, nitric acid—40 per cent, and water—20 per cent.

The smoothing efficiency can be seen once more to lie between the theoretical maximum and minimum and still to be closer to the former. It is not, however, so high as for electropolishing, apparently because of the greater agitation. This is borne out by the slight but definite decrease in smoothing which accompanies the increase in the rate of stirring from 60 to 180 rpm. It is noticeable, however, that the lower speed gives rather less consistent results. So far as smoothing is concerned, the bright dip gives results similar to those obtained by chemical polishing. The surface has an etched appearance, however, which shows even in the microsection as a definite roughness, though it is considerable only in specimens treated for a comparatively short time.

Discussion

According to the studies with a laminated anode, there is a maximum possible smoothing efficiency (approached in electropolishing copper in 50 per cent phosphoric acid) which corresponds to a wholly diffusion-controlled dissolution and, therefore, to the primary current distribution. A method of estimating this efficiency on a standard surface was proposed, depending on the fact that the family of lines representing successive stages of dissolution of a surface under such conditions corresponds with the equipotential lines near an enlarged negative replica of a section through the surface. The close agreement shown in Fig. 15 between the shapes of experimental and theoretical surfaces at successive stages of dissolution shows clearly that the rate of metal dissolution is diffusion-controlled in the examples studied. This agrees with the conclusions drawn from Part I of this paper. Smoothing results from the fact that a diffusion layer formed upon a rough surface has steeper concentration gradients on convex than on concave portions so that prominences are preferentially dissolved. The maximum possible smoothing efficiency is obtained when the influence of convection is negligible. In these circumstances, a steady-state diffusion layer exists in which the surfaces of equal concentration coincide with the equipotential surfaces for the electrostatic case. The distribution of attack over the surface is then the same as under primary current conditions. This explanation is compatible with the acceptor hypothesis proposed in Part I, although it requires no assumptions to be made regarding the nature of the ions or molecules whose diffusion controls metal dissolution. The mechanism might, therefore, be a completely general one applying to all electrolytic and chemical polishing processes.

The influence of diffusion in these processes is always great since the steepest possible concentration gradient must be set up before polishing can begin; according to the acceptor hypothesis, the suppression of crystallographic etching requires the concentration of acceptors at the surface to be zero. Thus, on the comparatively large irregularities of the microgroove surface it was found possible, by carefully shielding the anode, to attain the maximum smoothing efficiency (Fig. 15, 16, and 17). An increase in nondiffusive motion at the surface should reduce the smoothing efficiency, but the extent to which it does so would be expected to depend to a large extent on the size of the surface irregularities. It seems likely that on very small irregularities the smoothing efficiency will be close to the maximum under any conditions of polishing. With the microgroove surface, it has been shown that the expected reduction in smoothing power accompanies, in some cases, the removal of the shield from around the surface, reduction of viscosity, and increase in agitation (Fig. 18 and 20). The experiments under conditions of electrolytic etching showed a clear reduction in smoothing power when the rate of dissolution was reduced while other conditions remained the same. Since smoothing depends solely on concentration gradients near the surface, it was not expected that it would be affected by the cell voltage so long as it was within the polishing range; this was confirmed by the results at high and low voltage in Fig. 18.

Acknowledgments

The author wishes to record his thanks to the Decca Record Company for the supply of the electroformed standard surfaces and to the Director and Council of the British Non-Ferrous Metals Research Association for permission to publish the account of this work.

Grateful acknowledgment is also made to Dr. G. L. J. Bailey and Mr. E. A. Ollard for many helpful discussions.

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Society Progress and Comment on a National Problem

Presidential Address*

J. C. Warner

It has been a pleasure and an honor to serve as your president during the past year. There is clear evidence that the Society has made steady progress toward its objectives in the period since World War II, and because of the effective work of the Secretary's office, the directors and officers, the divisions, the editors, the local sections, and various committees, this progress has continued during the past year.

Our membership is increasing steadily. For example, we had 1,800 members on January 1, 1948, and 2,153 members on January 1, 1953. We had a net gain of slightly over 100 members during 1952. We do not seek to become a very large society because we recognize the great advantages which come from being able to become personally acquainted with most of our fellow members. Nevertheless, some growth is healthy, and a slightly larger society will put us in a sounder financial position from the standpoint of bringing about a further improvement in our publications and in operating an office which can be of more service to members. Some of us believe that we could increase our membership to 3,000 without losing the advantages we cherish.

The help we receive from industrial concerns as sustaining members of the Society has increased steadily. We are greatly indebted to Mr. Walter H. Prine and his committee for this desirable state and the important revenue which it provides. On May 1, 1952, we had support from 66 sustaining memberships; today support comes from 94 sustaining memberships.

I believe we have developed a better balance in Society interests. An increased interest in theoretical electrochemistry has been encouraged and this effort has been very fruitful. The Society's officers, directors, and editors want the Society to be a happy home for people with interests in both theoretical and applied electrochemistry—for university people as well as people from industry. This broader and more balanced interest has led to a substantial increase in the activities as well as in the size of our divisions and local sections.

The general character and professional level of any scientific or technical society is reflected in its publications. We can be proud of what the Society has accomplished in the field of its publications in recent years. We have established a successful monograph series in which several important titles have been published and additional titles are forthcoming. However, I would like to speak primarily about our JOURNAL. I was a member of a committee before World War II which studied the feasibility and desirability of establishing a monthly journal. We recommended the establishment of a monthly journal by the Society, but plans were tabled because of the war. These plans were revived by President James Lee after the war and our monthly JOURNAL was started on January 1, 1948. The format was changed to the present one on January 1, 1950, and there has been a steady increase in the quality, prestige, and number of subscribers to the JOURNAL. I believe the considerable increase in the number of nonmember subscriptions—these come largely from research libraries—is objective evidence of the increasing prestige of the JOURNAL. On January 1, 1950, we had only 453 nonmember subscribers; today the number is 1,114. The development of the JOURNAL to its present desirable state has required the devoted service and hard work of many able people. I would like to mention, first of all, Jim Lee who revived the monthly journal idea and pushed it vigorously until it became a reality. We are likewise indebted very much to Robert Burns, Herbert Uhlig, Frank LaQue, Harold Read, Norman Hackerman, Eleanor Reed Forrow, and Mrs. Ruth Sterns, for able and devoted service.

The present financial outlook for the Society is good. During the past several years we have been forced to approve budgets which anticipated a deficit in order to go ahead with our plans for developing the Society and improving our services to members. Fortunately some items of income have exceeded our estimates and good business management has resulted in some budget savings. Consequently, we have finished up the last few years with income and expense in balance or with only small deficits. This year, for the first time in several years, we have been able to make a budget which does not anticipate a deficit. This desirable state may be attributed to the following: a slightly larger membership, an increase in the nonmember subscriptions to the JOURNAL, an expansion of the sustaining membership program, and improved revenues from advertising in the JOURNAL.

Revenue from advertising deserves some special mention. When we embarked on the program of accepting advertising in the JOURNAL, we had hopes of obtaining at least moderate revenues which would permit us to go ahead with plans for increasing the size of the JOURNAL and the further improvement of its quality. We were disappointed and one of my first tasks as president was to undertake thorough discussions of the situation with our advertising agent. The upshot of these discussions was the agent's resignation, and we started over again—fortunately, this time with a man, Mr. Jack Bain, who has within less than a year convinced us that our original concept was sound. I am convinced that advertising in the JOURNAL can and will be a substantial source of revenue for supporting this important publication. I hope our members will cooperate with Mr. Bain when they can be helpful in promoting his program. In my opinion his program has been soundly and intelligently conceived.

In concluding this review of Society affairs, I would like to comment very favorably on the efficiency and devotion of our Secretary, Henry Linford, and his staff. We have good business management in the Society office and the objective of steadily improving our service to members. Our Secretary keeps the Board exceptionally well informed about Society affairs and problems presented to the Board are well formulated. He is very conscientious in carrying out the decisions and instructions of the Board. In my opinion, the Society is fortunate in having his services.

* * *

I would like now to speak briefly about another important matter—the consequences of letting political considerations or the demands of pressure groups in the market place override the conclusions and results arrived at by the applications of the objective methods of science.

About one and one half years ago, I spoke to the Physical-

* Delivered at the New York Meeting, April 14, 1953.

Inorganic Division of the American Chemical Society in this hotel about "America's Opportunity and Obligation as a Center of Learning," and of the importance to our citizens and to free peoples everywhere that we seize our opportunities and fulfill our obligations. I gave consideration to the conditions necessary for the establishment and growth of great centers of learning and the consequent great bursts of intellectual and creative achievement.

First of all, scholars and creative scientists and engineers must have intellectual freedom.

Secondly, society must have some understanding of the methods of science, and thus respect the results obtained by the application of this objective method. A corollary would say that society dare not let scientific truth be overridden by political pressures or the demands of the market place.

The prime prerequisite is intellectual freedom. But we have in our time seen the consequences of fascist and communist regimes overriding the objective findings of the physical and biological scientists, and we have seen them bring about a perversion of all scholarship in the humanities and social sciences, with a comparable deterioration in the creative arts as well.

The recent criticism of the National Bureau of Standards for its tests on Battery Additives and the consequent arbitrary dismissal of the Director of the Bureau, seem to me to be a case in point. It strongly suggests an attempt to override conclusions and results obtained by application of the objective methods of science. In any event, the charges which have been made question the scientific integrity of the Bureau. These are serious charges and, in my opinion, must be investigated promptly.

The integrity of such Government agencies as the Bureau of Standards must be beyond question if the Government is to protect the public through the Federal Trade Commission and Food and Drug Administration, etc. Indeed, I do not believe we could operate business in this country without confidence in our standards of weights and measures, established by the Bureau of Standards.

I am glad to be able to tell you that your Board of Directors agrees with these views and has adopted the following statement concerning the present crisis at the Bureau of Standards:

"The Electrochemical Society strongly condemns the dismissal of Director Astin of the National Bureau of Standards prior to a full and impartial investigation of charges which question the integrity of the Bureau. This arbitrary action of the Secretary of Commerce, casting doubt as it does upon the integrity and competence of Government scientists and Government laboratories, will seriously impair the operation of the Federal Trade Commission, the Food and Drug Administration, and other federal agencies established for the protection of the public. The Society takes a grave view of the challenge which this action implies to the promulgation of standards by Government laboratories. The Society is alarmed about the devastating effect of the summary dismissal of Dr. Astin upon the morale of technical personnel in the Government service and on the ability to recruit in the future such personnel. This unfortunate action is particularly lamentable in this period of international tension when the welfare of our citizens leans so heavily upon our ability to maintain superiority in science and technology.

"The Electrochemical Society urges that Congress authorize a thorough investigation of the scientific facts in the case, and invite the leading technical societies to nominate a group of qualified scientists and engineers to undertake this task and make public its findings.

"Finally, the Society believes that nothing short of restoring Dr. Astin to his former position can begin to repair the damage and injustice done the National Bureau of Standards, its director, and technical employees."

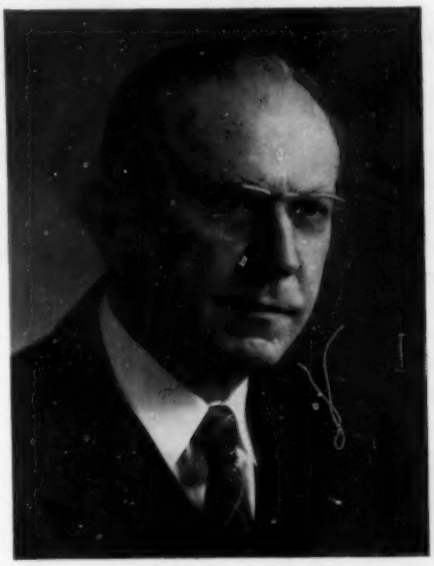
I am proud of the Board for making this direct and forthright statement. Copies of it are available, and I hope each of you who feels it proper to do so will use this statement in any way you see fit to urge an early investigation of the charges which have been made against the scientific integrity of the Bureau.

Current Affairs

Palladium Medal Award to Furman

Nathaniel Howell Furman of Princeton, New Jersey, has been designated by The Electrochemical Society as 1953 Palladium Medalist. Professor Furman will receive the second impression of the medal at the banquet on September 15th, held in connection with the fall meeting of the Society at Wrightsville Beach, North Carolina. He will deliver the Medal Award Lecture during the afternoon of the same day. The medalist is Russell Wellman Moore Professor of Chemistry and Chairman of the Department of Chemistry at Princeton University. Author of four books and more than eighty papers, he has made outstanding contributions to the field of analytical chemistry and particularly in the application of electrochemical principles to the development of new methods and techniques. Professor Furman received the 1948 Fisher Award for contributions to analytical chemistry.

Educated at Princeton, from which he received the Ph.D. degree in 1918, Dr. Furman holds an honorary D.Sc. degree from Boston University. He has been a member of this Society for many years and was president of the American Chemical Society in 1951. During World War II he made significant contributions to the Manhattan District Project.



Portrait by Orren Jack Turner

NATHANIEL HOWELL FURMAN

The Palladium Medal was established by the Corrosion Division of The Electrochemical Society in 1951, to be awarded for outstanding contributions to corrosion and to fundamental electrochemistry.

The first Palladium Medal Award was conferred on Dr. Carl Wagner in 1951, then Visiting Professor of Metallurgy at Massachusetts Institute of Technology, during the fall meeting of the Society in Detroit. Dr. Wagner was internationally recognized for his contributions to the theory of oxidation and tarnish of metals.

The metal used for the medal, and its design, have an interesting significance in connection with the award. The use of palladium explains the selection of the figure of the Greek goddess Pallas Athene, which appears on the back of the medal and after whom palladium, a member of the platinum group of metals, was named. Alchemical symbols of other metals surround the figure of the goddess, who, according to mythology, protects from the four Greek elements. Thus, the metals are secure against the corrosive influence of their environments

I.S.C.C. Urges Caution in Use of Unscientific Devices Intended to Prevent Corrosion

The Inter-Society Corrosion Committee has become greatly concerned about the hazards which may result from dependence on certain unproven devices for controlling corrosion and scaling. The Committee recommends that caution be exercised in the application of such devices, since any failure to give protection may result in serious damage to expensive equipment where a real problem of corrosion or scaling exists.

The Inter-Society Corrosion Committee is made up of about thirty-five delegates from major technical societies, in the United States and Canada, actively concerned with problems of corrosion control and with the scientific reduction of the economic loss caused by corrosion. By means of this word of caution, and in accordance with its established objectives, the Committee seeks to promote the use of the many scientifically sound and effective devices and processes which are presently available and to discourage dependence on unsound and ineffective methods of control.

The Committee wishes to draw particular notice to devices which are not based on any understandable scientific principles and which are generally promoted on the basis of testimonials from presumably satisfied customers, unsupported by quantitative data. Special attention is drawn to supposedly scientific explanations which make liberal and incoherent use of such terms as catalysis, magnetism, electronics, radiation, etc. Such "explanations" do not appear to have any basis in scientific fact.

In some cases recommendations are made by manufacturers that grounding wires of electrical circuits, if unfavorably connected to pipes in which the devices are installed, should be rearranged or connected elsewhere. The Committee emphasizes that if, because of installation of or after one of these devices has been installed, the electrical circuits are not grounded in accordance with the National Electrical Code, serious impairment of safety may result.

Against this background, and in line with its responsibilities, the Committee then recommends extreme caution in the application of devices for control of corrosion and scaling that are characterized by supposed operation without any apparent basis of sound scientific principles and for which no adequate engineering performance data are available.

Further Details on Fall Meeting at Wrightsville Beach

Plans for the fall meeting at Wrightsville Beach, September 13 through 16, are rapidly nearing completion, according to reports received from General Chairman LaQue and Finance Chairman Lowenheim. This is the first time the Society has met at this attractive location, which promises unusual opportunities both for entertainment and the holding of technical sessions.

Hotels and Reservations

Members will soon receive return postcard forms for their use in making hotel reservations. Prompt attention to this is recommended to insure a good choice of accommodations.

The Ocean Beach Hotel, convention headquarters, is ideally situated on the ocean, and offers first-rate facilities; it is further enhanced by its beautiful views. In addition, accommodations will be provided at the following nearby hotels: Kitty, Landis, Chandler, Hanover, Harrison's, Creasy, and Pullen.

The Ocean Terrace Hotel, convention headquarters

Plant Trips

Wrightsville Beach is a strictly residential resort community, and the adjoining area around Wilmington, North Carolina, is not highly industrialized electrochemically. Therefore, the plant trips will be restricted to visits to the Marine Corrosion Test Stations at Harbor Island—adjoining Wrightsville Beach—and Kure Beach about 18 miles away. A view of the Harbor Island Station was shown in the July issue of the JOURNAL and a picture of the Kure Beach atmospheric tests is provided in this issue. These facilities for studying marine corrosion will be of particular concern to the Corrosion Division and the Electrodeposition Division which will have programs at this meeting. The latter division will be especially interested in the many electroplated specimens among the nearly 30,000 exposed in the atmospheric tests lots at Kure Beach.

The Harbor Island Test Station is devoted to investigations of the deterioration of metals and other materials, including wood, plastics, and cordage by salt water and marine organisms. Many types of apparatus are used to study the corrosive and erosive effects of salt water throughout a wide range of conditions of flow. Tests range from the exposure of test coupons through trials of models of apparatus to the actual operation of full-scale equipment. The latter include heat exchangers, pumps, valves, piping, and large evaporator or distilling units. There will be in operation a cell for generating chlorine from natural sea water. The quantity of water supplied by pumps under pressure for the several tests at Harbor Island amounts to over seven million gallons per day—which is about the amount of fresh water used each day by the nearby city of Wilmington—population approximately 50,000. This is probably a record volume of liquid being provided solely for study of its corrosion effects.

A feature of the Harbor Island Station is a museum in which are displayed some of the most interesting specimens taken from tests at Kure Beach and Harbor Island during the past 18 years.

The Harbor Island Station is an easy walk across the bridge over the inlet that separates Harbor Island from Wrightsville Beach. Special buses will be provided to take visitors on the 18-mile trip to the Kure Beach atmospheric test lots.

Technical Program

Technical sessions are scheduled for Monday through Wednesday, September 14–16.

The Corrosion Division has planned an interesting program, featuring two special symposia: (1) Marine Corrosion, and (2) Titanium Corrosion. Also, corrosion papers of general interest will be presented. Corrosion sessions will be held on Tuesday and Wednesday, September 15-16 the latter to coincide with the first day of the annual meeting of the Sea Horse Institute.

The Electrodeposition Division has scheduled three sessions dealing with general electrodeposition problems, to be held on Monday, September 14 and Tuesday, September 15.

The Battery Division has planned two round-table discussions Monday A.M. and Monday P.M., September 14, on the following topics:

1. "Low Temperature Performance of Primary Batteries"—with J. J. Coleman of Burgess Battery Company as moderator.

2. "Corrosion of Positive Grids in Lead-Acid Storage Batteries"—with J. C. White, Naval Research Laboratory, as moderator.

The Electrothermic Division has scheduled a technical session on Tuesday A.M., and a round-table discussion on Tuesday P.M., September 15.

Sea Horse Institute

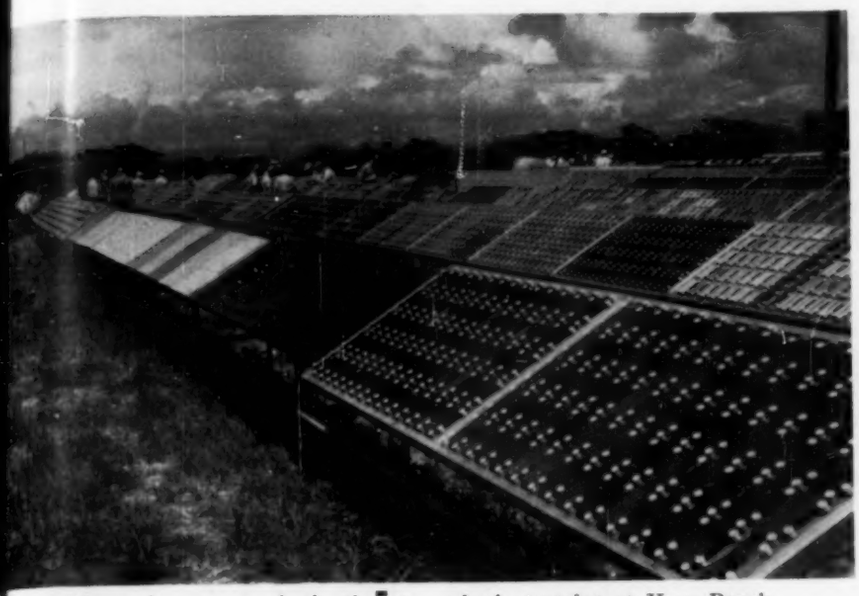
Many members are expected to stay over for the annual meeting of the Sea Horse Institute (September 16-18) and the Marine Borer Conference (September 17–18), which will follow The Electrochemical Society meeting.

Society Functions

The barbecue dinner scheduled for Monday evening, September 14th, should be a unique feature. The caterer promises to include the famous Brunswick stew—along with his extra special chicken barbecue—and all for a sum that will appear very modest in comparison with big city prices.

Additional Society functions highlighting the meeting will include:

The Palladium Medal Lecture by



Shown here are racks in the atmospheric test lot at Kure Beach

F. A. LOWENHEIM
Chairman, Finance Committee

Professor Furman at 4 P.M. on Tuesday, the 15th, in the comfortable, air-conditioned Crest Theatre.

The Society luncheon, to be held at noon on Wednesday, September 16th. The speaker for the occasion will be Judge Burney of the North Carolina Superior Court. Judge Burney's account of some of his experiences as a trial judge in this part of the world will be both entertaining and instructive.

The banquet and presentation of the Palladium Medal to Professor Furman, which whill take place at the Ocean Terrace Hotel on Tuesday evening September 15th. This will be preceded by a reception and followed by dancing.

Ladies' Program

Climatic conditions and the temperature of the ocean at the time of the fall meeting (about 75°F) should be such as to make the beach very attractive to the ladies. Special arrangements that are being made for their entertainment include trips to some of the nearby gardens and plantations, and guided tours to the many historical sites in the vicinity of Wilmington.

Other Society features in which the ladies will participate are the general Society luncheon on Wednesday noon, September 16, the barbecue dinner on Monday evening, and the banquet on Tuesday evening, following which music will be provided for dancing.

Division Activities

The Battery Division has planned a luncheon and business meeting on Monday, September 14.

The Corrosion Division will hold a special luncheon for members and guests at 12:15 P.M. on Tuesday, September 15. Following the luncheon, at about 1:30 P.M., the division's business meeting will be held.

The Electrodeposition Division will also hold a luncheon on Tuesday, September 15.

* * *

The complete Technical Program for the meeting will be published in the September issue of the JOURNAL.

1953 Awards by Electroplaters' Society

The Electrochemical Society members named below received, or shared, the awards listed, made by the American Electroplaters' Society at the Convention in Philadelphia on June 15:

William C. Geissman, National Lock Company, Rockford, Ill.—The Carl E. Heussner Award, the top award of the society.

R. F. Ledford, Industrial Filter & Pump Manufacturing Company, Chicago, Ill.—The A. E. S. Silver Medal.

Lloyd Gilbert, Rock Island Arsenal, Rock Island, Ill., and W. S. Morrison, Illinois Water Treatment Co., Rockford, Ill.—The Chromium Plating Award.

Harold J. Wiesner, Bendix Aviation Corporation, South Bend, Ind.—The Precious Metal Plating Award.

Bockris Appointed to U. of Pennsylvania

J. O'M. Bockris, Lecturer in the Department of Inorganic and Physical Chemistry at Imperial College, London, has been appointed Visiting Professor in the Department of Chemistry at the University of Pennsylvania, beginning this fall. His appointment supplements the present program of teaching and research in electrochemistry at the University.

Dr. Bockris visited this country in 1951 on the occasion of the Bureau of Standards' Semicentennial Celebration, and the Bureau's Symposium on Electrochemical Constants. At this time, he lectured at various universities and industrial laboratories summarizing his electrochemical researches at Imperial College. He presented the Richards Memorial Address at the Washington Meeting of the Society in April, 1951, on the subject of overvoltage. He has also lectured at universities in Canada, Germany, Norway, Sweden, and Belgium. Dr. Bockris is co-author with G. Kortüm of the two-volume work "Electrochemistry," published in 1951, and he has contributed many papers to the technical literature dealing with electrode reactions, constitution of ionic liquids, and high temperature slags.

Westvaco to Have Sulphur Recovery Unit

The Westvaco Chemical Division of Food Machinery and Chemical Corporation has signed a contract for the design and installation of a plant for the conversion of hydrogen sulfide to sulphur in connection with their carbon bisulfide plant at South Charleston, West Virginia.

New Research Lab for AMF

American Machine and Foundry Company has purchased a building in Springdale, Connecticut, for the establishment of a chemical research and development laboratory. Transfer of the equipment and personnel from the present Brooklyn plant is expected to be completed by October 1.

SECTION NEWS

Cleveland Section

The Cleveland Section closed its current season on May 15 with their usual well-planned "Ladies' Night." Features of the program were an enjoyable dinner at Damon's Restaurant, followed by a theater party.

Preceding the social activities, the following new officers were elected for Section for the 1953–54 season:

Chairman—N. C. Cahoon, National Carbon Company

Vice-Chairman—Ernest B. Yeager, Western Reserve University

Treasurer—W. H. Stoll, National Carbon Company

Secretary—Merle E. Sibert, Horizons, Incorporated

J. M. MARGOLIS (1952–53)

Washington-Baltimore Section

The Washington-Baltimore Section met on May 21 at the National Bureau of Standards, and heard guest speaker John K. Taylor, Physical Chemistry Section, National Bureau of Standards, speak on "The Theory and Application of Polarography."

Dr. Taylor discussed the fundamental principles of polarography which is based on the interpretation of current-voltage curves obtained in electrolysis with the dropping mercury electrode. The experimental conditions necessary for precise measurements were discussed along with the advantages and limitations of polarographic analysis. While polarography continues to find increasing use in analytical chemistry, a number of other applications were pointed out. Among those considered were the applications to the study of complex ions and electrode reactions.

The very interesting talk by Dr. Taylor was followed by a lively discussion from the floor.

At the business meeting the following officers were elected to serve for the coming fiscal year:

Chairman—Samuel Eidensohn

Vice-Chairman—D. T. Ferrell, Jr.

Secretary-Treasurer—Fielding Ogburn

FIELDING OGBURN, *Secretary*

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PERSONALS

JEROME STRAUSS, vice-president, Vanadium Corporation of America, New York, was honored by the American Society for Testing Materials during the 56th annual meeting in Atlantic City in June, when he received one of the 1953 Awards of Merit. Mr. Strauss was cited for his distinguished service as the longtime chairman of ASTM Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and related alloys since its inception in 1929, and for other contributions to the society.

E. C. PAYNE has accepted a position as research chemist with the U. S. Atomic Energy Commission, New Brunswick, N. J. Mr. Payne was previously connected with Sylvania Electric Products Inc.

WILLIAM R. VEAZEY, connected for many years with research and administration at The Dow Chemical Company, retired on June 2 after 37 years of service with the company, including 26 years as a member of the board of directors. Dr. Veazey was president of The Electrochemical Society during 1945–46.

J. D. HANAWALT, manager of the Magnesium Department, Dow Chemical Company, has been appointed a vice-president of the company, according to an announcement of the board of directors on June 2.

E. S. BUNN, Revere Copper and Brass, Incorporated, formerly at the Aluminum Division, Baltimore, has transferred to the company's office in New York City.

E. S. BYRON, Westinghouse Electric Corporation, Bloomfield, N. J., has accepted a position as manager, Metallurgical Research, Sylvania Electric Products Inc., Towanda, Pa.

MARIA TELKES has joined the Research Division, New York University, University Heights, New York. Dr. Telkes was previously on the staff of Massachusetts Institute of Technology, Cambridge, Mass.

C. ROGERS MCCULLOUGH, former staff engineer, has been appointed an assistant director of Monsanto Chemical Company's General Development Department.

NORMAN HACKERMAN, professor of chemistry at the University of Texas and Technical Editor of the JOURNAL, has been appointed a consultant on hydrogen bomb production for the Atomic Energy Commission.

W. CHARLES COOPER has resigned from the Chemistry Department, University of Wisconsin, Madison, Wis., to accept the position of senior chemist, analytical chemistry, at Canadian Copper Refiners Ltd., Montreal, Canada.

HIRAM S. LUKENS, Blanchard Professor of Chemistry at the University of Pennsylvania, Philadelphia, retired from active teaching on June 30 after 46 years on the faculty. Dr. Lukens was acting dean of the University's Towne Scientific School in 1937–38, director of its department of chemistry and chemical engineering from 1932–51, and head of the chemistry department in 1951–52. He was president of The Electrochemical Society in 1934–35.

WILLIAM BLUM, former Society president, and on the staff of the National Bureau of Standards from 1918 until his retirement in 1952, received the honorary degree of Doctor of Science from the University of Pennsylvania at its 197th Commencement, in Philadelphia, on June 10. The honor came to Dr. Blum just 50 years after he was graduated from the University, in 1903, with the degree of bachelor of science in chemistry.

B. C. CASE is now finishing superintendent, Sunbeam Corporation, Chicago, Ill. Mr. Case was previously with Hanson-Van Winkle-Munning Company, Matawan, N. J.

RALPH HOECKELMAN has left Battelle Memorial Institute, Columbus, Ohio, to join Courter Electric Products, Inc., Boyne City, Mich. Mr. Hoeckelman was the 1951 winner of the Society's Young Author's Prize.

ALFRED H. TAYLOR, JR., has been promoted to manager of the Analytical Division, Air Reduction Company, Inc., Research Laboratories at Murray Hill, N. J.

FRANK G. BREYER of Singmaster & Breyer, New York City, received the honorary degree of Doctor of Engineering from Clarkson College of Technology, Potsdam, N. Y., on May 31st during the 1953 commencement ceremonies.

NEW MEMBERS

In June 1953, the following were elected to membership in The Electrochemical Society:

Active Members

E. Robert Breining, General Motors Research Division, 485 W. Milwaukee Ave., Detroit, Mich. (Electrodeposition)

Thomas G. Bullen, Iona College, Faculty Residence, 33 Beechmont Dr., New Rochelle, N. Y. (Electronics and Electrothermic)

John W. Dzimianski, Allis-Chalmers Corp., mailing add: 1943 N. 86 St., Milwaukee, Wis. (Electric Insulation)

William C. Fink, Sylvania Electric Products Inc., Montoursville, Pa. (Corrosion, Electrodeposition, Electronics, and Theoretical Electrochemistry)

Curry E. Ford, National Carbon Company, P.O. Box 6087, Cleveland, Ohio (Corrosion and Industrial Electrolytic)

John R. Gormley, Sylvania Electric Products Inc., mailing add: 6 Third St., Towanda, Pa. (Electronics)

Carl J. Lang, Oakite Products, Inc., mailing add: 233 W. 13 St., New York, N. Y. (Electrodeposition)

Edwin A. G. Liddiard, Fulmer Research Institute, Stoke Poges, Bucks, England (Corrosion)

Donald W. Mayer, Tung-sol Electric, Inc., mailing add: Box 145 Fairview Ave., Colonia, N. J. (Electronics)

Frank Passal, United Chromium Inc., mailing add: 19757 Edinborough, Detroit, Mich. (Electrodeposition)

W. H. Pearlson, Minnesota Mining & Mfg. Company, mailing add: 367 Grove St., St. Paul, Minn. (Electro-Organic)

Frank Schultz, National Lead Company, mailing add: 48 Hanson Ave., Fords, N. J. (Electrodeposition and Theoretical Electrochemistry)

Vanja M. Srepel, General Electric Company, mailing add: 220 Roxford Rd., N., Syracuse, N. Y. (Electronics)

Robert Yates, Dow Chemical Company, Freeport, Texas (Industrial Electrolytic)

Reinstatement

Robert L. Johnson, American Metallic Chemicals Corporation, mailing add: 2807 S.E. Olsen St., Milwaukie, Ore. (Industrial Electrolytic)

Associate Member

Marshall E. Peterson, Ray-O-Vac Company, 212 E. Washington Ave., Madison, Wis. (Battery and Electronics)

BOOK REVIEW

Comité International de Thermodynamic et de Cinetique Electrochemiques—Proceedings of the IIIrd Meeting, 1951. Published by Carlo Manfredi, Milan, Italy, 1952. XVI plus 495 pages, 8000 lire.

The International Committee of Electrochemical Thermodynamics and Kinetics is an association devoted to the informal collaboration and the exchange of information and ideas in the electrochemical field. This volume, the record of the third meeting of the Committee, should be of interest to all scientists desiring a knowledge of current work in the field.

In a compilation of this kind it is, of course, difficult to achieve complete unity, styles and approaches as well as subject matter varying as much as they do from paper to paper. In the face of these difficulties the editors and program committee have done an admirable job.

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Roughly equal emphasis has been given to the experimental and theoretical approaches and all of the thirty-six papers are devoted to problems of fundamental interest.

The papers are divided somewhat arbitrarily under the headings:

1. Electrochemical Behavior of Metals and Metalloids.
2. Double Layer Electricity.
3. Nomenclature and Electrochemical Definitions.

Under the first heading we find such varying topics as Equilibrium Potential-*p*H Diagrams of Several Elements by Delahay, Pourbaix, and Van Rysselberghe; Passivity of Metals by Piontelli; Anodic Surface Films by Hoar; and Electrochemical Oscillations by Meunier. Three papers in the Double Layer section should be of particular interest to theoretical electrochemists. One of these, by F. O. Koenig, gives a careful thermodynamic analysis of the Volta effect.

The format of the book is uniformly good, care having been taken in such matters as figure captions, tables of definitions of terms in theoretical papers, and lists of references. Perhaps the only drawback from the standpoint of American readers is that most of the papers are in French. Taken as a whole, this compilation is a valuable one deriving its unity from the timeliness of its papers.

J. F. DEWALD

NON-AQUEOUS SOLVENTS by L. F. Audrieth and J. Kleinberg. Published by John Wiley & Sons, Inc., New York, 1953. 273 pages, $6.75.

The book represents a survey of those chemical reactions which have been carried out in the more extensively studied nonaqueous solvent media. As expressed by the authors, it is designed "to appeal more specifically to those . . . interested in synthetic chemistry." Following a general discussion of solvents and current acid base theories, a full hundred pages are devoted to studies carried out in liquid ammonia and ammonia derivatives.

Acetic, sulfuric, and hydrofluoric acids are used to illustrate those reactions which assume importance in typical protonic solvents. The reactions cover a wide range of organic and inorganic substances. Chapters on sulfur dioxide and the acid chlorides serve to point out the successful extension of the solvent system theory to aprotic solvents. The authors have included some of the recent work done using the interhalogens as solvent media, and a final chapter is devoted to high temperature systems.

The authors have left to others the treatment of the usual organic solvents, and little attention is given oxidation reduction reactions in which the solvent presumably does not play an important role.

TOM D. SCHLABACH

LETTER TO THE EDITOR

Electrode Carrying Capacity

Dear Sir:

In an article on phosphorus furnaces,[1] Harry A. Curtis disagrees with a formula I use to determine the safe carrying capacity of an electrode. In an open ferroalloy furnace the part of the electrode which is liable to be overloaded is situated between the top of the charge and the holder. The temper-

[1] H. A. CURTIS, *J. Electrochem. Soc.*, **100**, 81*C* (1953).

New Address

FOR

The Electrochemical Society, Inc.

216 West 102nd Street New York 25, N. Y.

Telephones—RIverside 9-0602 and RIverside 9-0603

The Electrochemical Society has moved its offices to larger quarters, located on the southeast corner of 102nd Street and Broadway. This is diagonally across Broadway from the former location. After July 1st, all communications to the Society and the JOURNAL should be addressed to the new number, *216* West 102nd Street. Telephone numbers remain the same.

ature is the limiting factor. If a certain temperature is chosen to correspond to maximum safe load, the heat losses per square foot are the same whatever the size of the electrode, and if balanced conditions exist, which is very nearly the case above the charge, the heat generated must equal the losses

$$\frac{I^2\rho l}{\pi D^2} = K\pi Dl \text{ or } I^2 = bD^2$$

where: I = current in amperes, ρ = resistivity of electrode material, l = arbitrary length of a section of electrode in inches, $K = 4h(T_e - T_a)$ where h = heat transfer coefficient in watts/in.^{2}/°C, T_e = temperature of electrode, and T_a = temperature of air. This is the equation Mr. Curtis does not approve. In a closed furnace, conditions are perhaps different, but it is not too far fetched to assume that if the temperature above the roof is kept the same for all sizes of electrodes the conditions under the roof will also be the same. Such must be the case because the current carried by the electrodes of Mr. Curtis' furnaces (as listed in Table VI, page 85C) follow the rule rather nicely. Eliminating furnace 4, which is admittedly out of line, the average current for a 30-in. electrode is 15,400 amp and for a 40-in. electrode 24,200 amp. In the first case, b = 8800, in the second, 9170. If a constant of 9000 had been chosen, the current for a 30-in. electrode would have been 15,600 amp, and 23,400 amp for a 40-in. electrode, both values being very close to his own average.

For a designer planning a line of furnaces the formula is intended to give a sound starting point, and has proved very useful.

F. V. Andreae
351 Derby Circle,
Chattanooga, Tennessee

LITERATURE FROM INDUSTRY

High Vacuum Pumps. New, extensively revised edition of the 36-page catalogue, "Stokes Microvac Pumps for High Vacuum," just issued, includes valuable tables of formulas, constants, and conversions used in vacuum processing; pump selection for typical vacuum systems, and information on continuous oil purification, etc. Installations of pumps include freeze-drying of biologicals, metallizing of both metal and plastic parts, and evacuation of high altitude testing chambers, cyclotrons and atomic diffusion vessels. F. J. Stokes Machine Co. P-146

Corrosion-Resistant Cements. Comprehensive chart shows resistance of seven classes of corrosion-resistant cements to 297 of the most generally used corrosive chemicals. For use as a guide for engineers, maintenance men, and purchasing agents in selecting chemical-resistant cements to meet particular problems. Pennsylvania Salt Mfg. Co. P-147

Silver-Zinc Storage Cells. Technical data sheet describes new cell Models HR85 and HR90; weights, 53 ounces each and volume approximately 47 cu in. Capacity 100 amp/hr. Yardney Electric Corp. P-148

Tergitol Dispersant NPX. A non-ionic, surface-active agent with outstanding detergent, dispersing, and emulsifying properties, is described in new 6-page technical information sheet just released. Includes information on physical properties, shipping data, solubility characteristics, wetting power, stability and compatibility, physiological action, and applications. Suggested formulations are also given. Union Carbide and Carbon Corp. P-149

General Purpose Relays. Complete new line of general purpose relays, featuring longer life and greater flexibility of application, is described in illustrated folder. The new relays, designated as CR2790-E, are rated from 6 to 300 volts; 60, 50, and 25 cycles plus, d.c.; and 10-amp continuous contact rating. General Electric Co. P-150

NEW PRODUCTS

Box Draw Furnace. An electric box draw tempering furnace designed for applications requiring no protective atmosphere is available. Used for batch drawing or tempering high volume work that can be handled on trays. Six sizes ranging from 15 x 24 x 12 inches to 42 x 72 x 30 inches. Westinghouse Electric Corp. N-18

Electronic Relay. New Electronic Control, "Elpheo" Electronic Relay Model No. 3, is now available. Designed especially for use with mercury thermoregulators in the chemical laboratory. Electro-Physics Co. N-19

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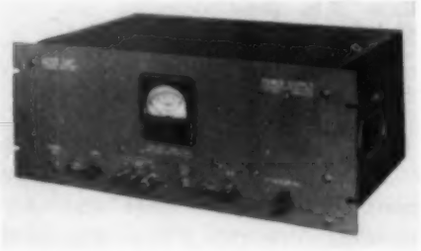

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To receive further information on any New Product or Literature from Industry listed above, send inquiry, with key number, to JOURNAL of The Electrochemical Society, 216 West 102nd Street, New York 25, N. Y.

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RECENT PATENTS

Selected for electrochemists by Fred W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

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Mansoff, A. P., 2,626,971, Battery Heater

Marquardt, A. E., 2,626,972, Storage Battery Transporting Cart

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Gardiner, W. C., 2,627,501, Apparatus for Electrolysis of Alkali Metal Compounds

Fastie, W. G., 2,627,530, Ambient-Temperature Compensated Device

Vogt, H., 2,627,531, Porous Electrode

Wilke, M. E., 2,627,532, Electric Battery with Cross-Over Intercell Connectors

Jensen, H. E., 2,627,533, Battery Terminal Post Mounting

Arbogast, R. D., 2,627,534, Battery with Conductive Cement Intercell Connections

Hall, C. I., 2,627,570, Thermosensitive Resistance Element Containing Eutectic Mixtures

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Smith, A. L. J., 2,628,201, Zinc-Magnesium Oxide Luminescent Materials and Methods of Making Same

Balaguer, R. R., 2,628,261, Dry Electric Battery

Paterno, J. J., 2,628,262, Battery Connector

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Johnston, Samuel S., and Elswick, John E., 2,628,924, Method of Cleaning Strip

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Earnest, William K., and Karr, Errol H., 2,628,935, Electrolytic Production of Chlorates

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Committees of the Society

The increasing activity of the Society places more work and responsibility on the members of the committees and particularly on the chairmen. It is gratifying to find that this work is being undertaken willingly both by men who have already been proven pillars of strength in the Society, as well as by newer personnel from whom we anticipate leadership in the future.

An effort is being made to confine the committees and the Society representatives to those who will actually produce useful results, and to discontinue any inactive groups. We know that most of our committee members take their responsibilities seriously and we look forward to a continuation of this feeling to produce effective results in the year ahead.

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April 28, 1953

Knechtel, M. D., 2,636,817, Method of Decreasing Dross Formation in the Melting of Zinc

Nicholson, K. C., 2,636,825, Refractory Carbide and Nitride Product and Method of Making

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Editorial

The Phenomenon of Southern California—Its Growth and Electrochemical Future

ONE hundred years ago, Los Angeles was a pueblo of 1600 persons governed by Mexican law and custom. Today, Los Angeles has 2,100,000 residents and is the metropolis of the greater Southern California-Nevada area, which is more than three times as large in population. Tracing the history of this phenomenal transformation, one is impressed with the fact that the city's greatness did not come naturally. For example, there was no natural harbor, little timber, no mining bonanza, no navigable river, and strictly limited water supplies.

But the salubrious climate, the fertile soil, the discovery of oil, the energy and vision of the people induced a rapid growth. A harbor was built out of mud flats where none existed before, railroads were thrust across the desert and down the coast, and water and power were brought hundreds of miles from the snow-capped Sierras and from the Colorado River to Los Angeles.

Most of the time, the supply of power and water was not far ahead of the demand. However, there was a brief period following the completion of Hoover Dam, just prior to World War II, when there was a substantial surplus of low-cost power. This surplus, together with local mineral resources previously underdeveloped, led to the creation of a new segment of the electrochemical industry which nearly collapsed following the conclusion of World War II, but is now flourishing.

The Regional Feature which appears in this issue of the JOURNAL presents a history of the development of the electrochemical industry in the Southern California-Nevada area, an assessment of the present status, and a qualified prediction of future trends.

—JOSEPH C. SCHUMACHER

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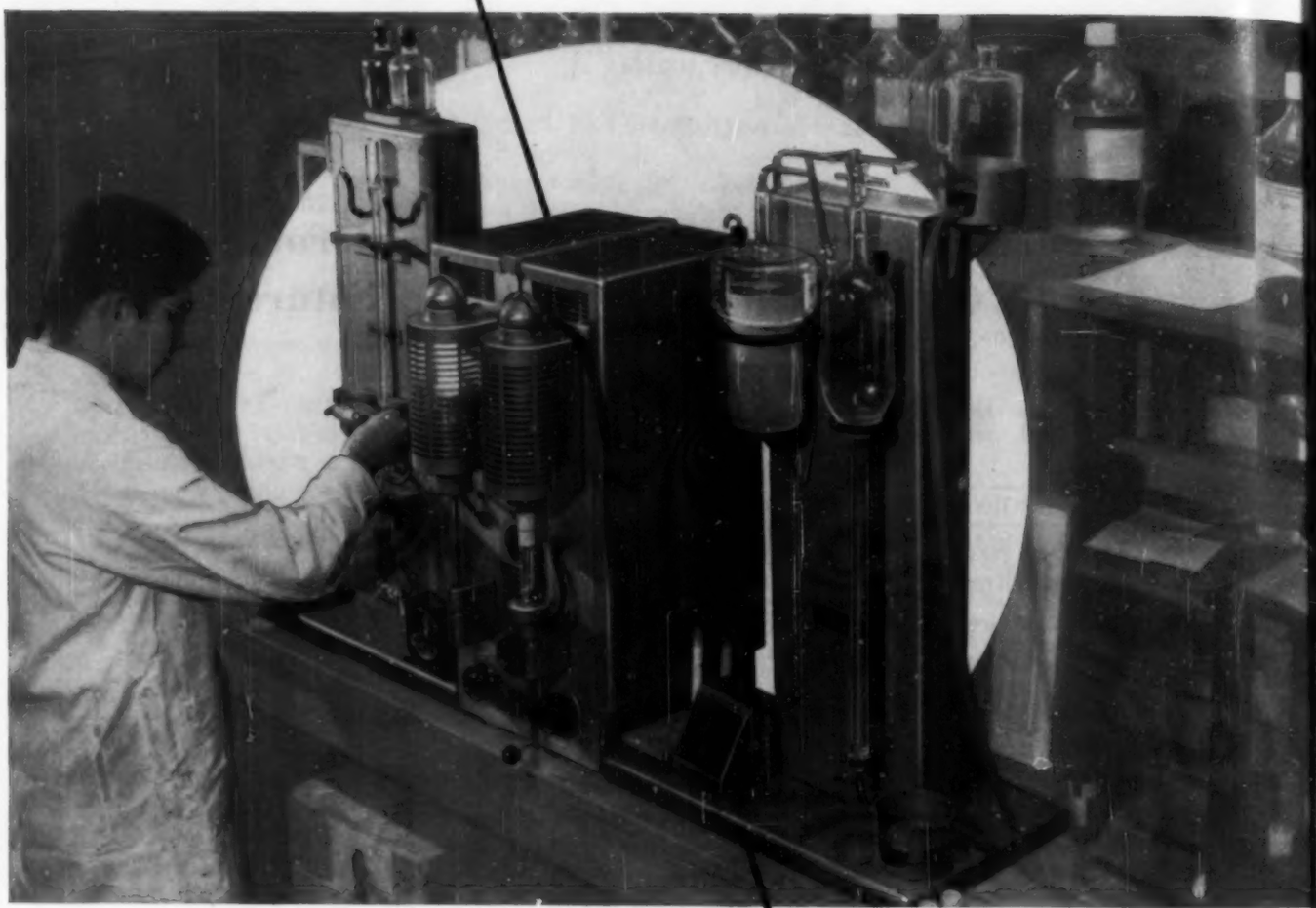

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Southern California—Nevada Area

Joseph C. Schumacher[1]

Introduction

Southern California has often been described as the region south of the Tehachapi mountain range which cuts across California to the sea just north of Santa Barbara; and southern Nevada as the wedge-shaped region facing Southern California on the southwest and Lake Mead, formed by the Colorado River, on the east. The Southern California-Nevada area, for the purpose of this article, may be described as consisting of 15 southern counties of California: Fresno, Imperial, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, Ventura, Inyo, Kings, Mono, and Tulare, and Clark county in Nevada. This territory covers 84,089 square miles and has a population of approximately 6.5 million. No region in America is dominated by one city to the extent that Los Angeles, with its 450 square miles of territory, dominates Southern California, according to the geographers, White and Foscue. This statement might well be extended to include southern Nevada. Conversely, Los Angeles is dependent for its very existence on the water and power imported from distant points in Mono County, 350 miles to the north, and in Clark County, 266 miles to the northeast.

The earliest electroprocess operation in the Southern California-Nevada area dates back to about 1916, when steel was produced in an electric-arc furnace at Los Angeles. This installation was the start of a development which has made California the fifth ranking state in electric steelmaking capacity, at the beginning of 1953, and there is a good indication of an additional substantial increase in capacity. The first commercial electrosmelting plant in the area is due to go into operation in 1953. Total electrothermic demand now accounts for approximately 130,000 kw.

Electrochemical manufacturing started in the Southern California-Nevada area in 1941. This new industry had a modest beginning that was followed by a rapid expansion to great proportions, only to be cut back sharply in 1944. The slim thread of activity that remained shortly after World War II in 1945 has since become sturdy, with new and zestful, although less spectacular, growth. Great hope is now apparent for a bright and permanent future in this field.

Just as in the case of the Niagara, TVA, and Pacific Northwest electroprocess-industry centers, the primary attractive force in the Southern California-Nevada area was cheap hydroelectric power. The story of power development in the area is as romantic as any that could be told about men with vision, desire, and the necessary fortitude, who reached out and brought water and power to this semiarid region. The phenomenal population and industrial growth would not have been realized had it not been possible to import water and power from distant sources. A new trend was started in 1904, when the Southern California Edison Company began transmitting power to Los Angeles from generating plants on the Kern River. Soon thereafter, the resources of the San Joaquin River, 248 miles to the north of Los Angeles on the western slope of the Sierra Nevada mountain range, were tapped for power, and the Owens River, 265 miles to the north on the eastern slope, was tapped for both water and power.

In 1930, the total generating capacity of the various utilities, both public and private, had reached 635,000 kw of hydroelectric and 712,000 kw of thermoelectric. At first, thermogenerating capacity was installed as stand-by and emergency reserve, but, later on, because of the advent of supplies of low-cost natural gas and oil, this capacity became firm.

It was quite apparent, as early as 1924, that the potential water supply would have to be increased or Southern California would stop growing. This time, attention was focused on the Colorado River. The project involved not only the construction of the Colorado River aqueduct, but also the construction of Hoover Dam, then Parker and Davis Dams downstream, and the prospect of building Bridge Canyon and Glen Canyon Dams upstream.

When Hoover Dam power plant came into operation in 1936, there was a temporary surplus of electric power in the area that was taken up in the early 1940's by the war-born industries. This surplus power proved to be a major factor in the subsequent industrial growth, generally, and, in particular, in the field of the electrochemical industries.

First came a privately owned, commercial potassium-chlorate plant that has since grown to many times its original size. In rapid succession came the giant Government magnesium-reduction plant in Nevada and the aluminum-reduction plant in Los Angeles. The magnesium plant was in operation for about two years.

[1] Journal Regional Editor, Los Angeles. Western Electrochemical Company, Culver City, California.

The aluminum plant was in operation also for about two years, at less than planned capacity. It was then shut down after war quotas had been filled. All of the

Map of the lower Colorado River region, showing the large dams concentrated in this area.

equipment was eventually removed, thereby eliminating the possibility of reactivation of the facility. The magnesium plant was shut down after a mountainous stockpile of magnesium metal had been accumulated. It was later partly cannibalized, but through the pioneering efforts of the State of Nevada and a few lessees, a large part was kept intact. A number of new electroprocess industries have sprung out of the remains.

Electrometallurgical Experiment Station

In 1936, the U. S. Department of Interior, Bureau of Mines, established an electrometallurgical experiment station at Boulder City, Nevada. The purpose of the laboratory was to develop commercially practicable methods for the utilization of raw materials from the surrounding area and the surplus of electric power from nearby Hoover Dam. Initially, the electrodeposition of manganese metal, the beneficiation of low-grade chromite ores, and the recovery of potassium sulfate and alumina from Utah alunites were investigated on a small scale.

The basis for expansion of both the scope and scale of operations was provided by the Strategic Minerals Act of 1939, and the advent of war in Europe. Since that time, research and development work has been directed toward, but not limited to, electroprocesses for the production of metals of strategic importance from the national defense viewpoint.

Major projects that have been satisfactorily completed on the pilot-plant-scale level include the following: production of electrolytic manganese metal and metallurgical-grade manganese nodules from low- and off-grade domestic manganese ores; production of electrolytic chromium metal and ferrochrome from low-grade, high-iron domestic chromites; production of electrolytic magnesium from magnesites and dolomites; production of zinc from low-grade oxidized ores. Smaller-scale electrolytic work has also been completed on certain ores for production of copper, nickel, antimony, and various metallic borides.

Titanium was developed from a laboratory curiosity to a strategically important metal after preliminary tests had shown that titanium could replace several scarce metals for certain applications. The Kroll process for making titanium sponge was selected in 1942 as being the most promising for development. This process produces titanium sponge by the reaction of titanium tetrachloride with magnesium. The reaction itself is not electrochemical, but depends upon the electrolytic production of magnesium and chlorine. An integrated plant electrolyzes the magnesium-chloride slag resulting from the Kroll reaction to regenerate magnesium and chlorine. The chlorine, along with any necessary make-up, is used to prepare titanium tetrachloride which is recycled to the process. A ¾-ton-per-day pilot plant was put into operation at Boulder City and is still operating today on cost reduction investigations. Research on direct electrolytic processes for titanium also is being carried out by the Bureau of Mines, along with several major industrial and potential producers.

Original work on electrolytic manganese was carried out at Reno, Nevada, and was transferred to Boulder City in 1936. A one-ton pilot plant was operated at

Boulder City from 1942 to 1946. Pilot-plant tests were made on most of the larger deposits of domestic manganese ore known at that time. Manganese research has also been carried out on several of the larger low-grade deposits, to produce standard metallurgical-grade nodules for use in commercial ferroalloy furnaces. Efforts have been concentrated on the production of material for standard furnaces, rather than the utilization of substandard material in special furnaces.

An economic process for producing electrolytic chromium from trivalent solution was pioneered at Boulder City, and a small pilot plant was operated for several years. The demand for high-purity chromium is increasing rapidly to meet demands for high-temperature alloys. Research has shown that the high-iron, domestic chromites can be successfully used under emergency conditions for production of ferrochrome and chromium chemicals.

Aerial photograph of Los Angeles harbor

Metals

Magnesium

In August 1941, a contract was signed whereby Basic Magnesium, Inc., undertook to furnish magnesium metal producing facilities for the Defense Plant Corporation at a site convenient to Hoover Dam power, the magnesite deposits at Gabbs, Nevada, and salt at Amboy, California. Basic Magnesium, Inc., was originally a corporation formed by Magnesium Elektron, Ltd., of Manchester, England, and Basic Refractories, Inc., of Cleveland, Ohio. In October 1942, Anaconda Copper Mining Company, at the invitation of the Government, assumed direction of Basic Magnesium, Inc., through purchase of the controlling interest held by Basic Refractories. The status of Magnesium Elektron was not affected by this change.

This plant, the largest of its kind ever built, is located at Henderson, Nevada, between Las Vegas and Hoover Dam. The first metal was produced in August 1942, and the plant was in full operation in June 1943. It was a major factor in the eightyfold, war-time expansion of magnesium-producing facilities in the U. S. During the first quarter of 1944, Basic Magnesium, Inc., produced more than 25 per cent of the total for the U. S. Production for one month in the same period was about one and one half times as much as the total for the U. S. in 1939. The average daily output was greater than the designed capacity of 153 tons for the period July 1943 to April 1944.

Two 230-kv transmission lines, each about 16 miles long, were constructed over widely separated routes between the Hoover Dam power house and Basic Magnesium, Inc., to supply the 200,000-kw demand reached during the period of peak production.

The process, previously described by R. H. Ramsey (1, 2), included a number of unique features, for example, anhydrous magnesium chloride was produced in specially designed electric furnaces by reacting magnesium-oxide pellets containing carbonaceous reducing agents and chlorine gas at temperatures above 850°C. Liquid anhydrous magnesium chloride was tapped from the bottom of the electric furnaces, and the red-hot watery liquid was then added to electrolytic cells, wherein magnesium metal and chlorine were produced at current efficiencies reported to be above 85 per cent of the theoretical values. The cells operated at a current of 20,000 amp. Chlorine recovered from the electrolytic

cells was then recycled to the electric furnaces together with make-up chlorine supplied from the chlorine-caustic plant.

War quotas having been met, the plant was shut down in November 1944. This event made possible the beginning of the diversification of use that eventually led to the adaptation and use of the facilities today.

Western Electrochemical Company, in January 1945, undertook to build a potassium perchlorate plant for the Defense Plant Corporation, utilizing a part of the facility. Stauffer Chemical Company, in May 1945, took over the operation of the chlorine and caustic plant. In March 1948, the State of Nevada, in a bold effort to save this giant white elephant for a permanent industrial settlement, purchased the entire facility from the U. S. Government. The State, through its Colorado River Commission, proceeded first to lease the unused portions, then to divide up the entire facility, and finally to make it available in parts to the various companies that had been attracted there and had put the facilities to use.

Five companies, Pioche Manganese, Stauffer Chemical Company of Nevada, Titanium Metals Corporation of America, U. S. Lime Products, and Western Electrochemical Company, have put to use parts of the original facilities suited to their particular type of manufacturing. All except one, U. S. Lime Products, are electroprocess industries, and for that reason are described later in this article. Utilities and common facilities to the various plants have been sold to a sixth company, Basic Management Corporation, owned jointly by the five resident owners. The entire facility has thus been put in the hands of private industry. It is interesting to note that the original town site has grown considerably and has recently become a chartered city (population over 10,000) of the State of Nevada.

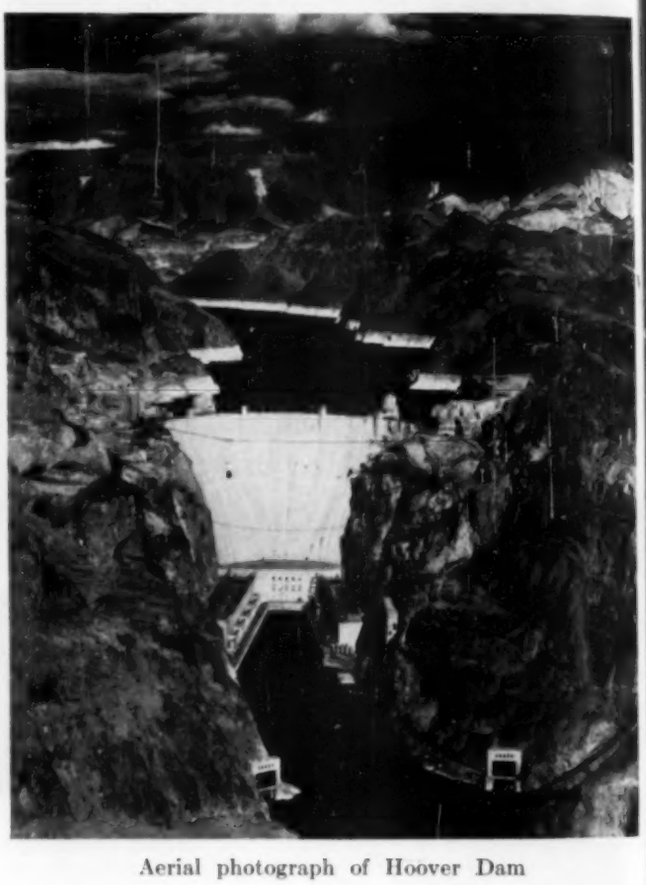
The composite electrical load of the various companies located at Henderson now amounts to a demand of 112,000 kw. Negotiations are under way to provide additional power needed for immediate growth by the purchase of off-peak power from the Arizona-California-Nevada power pool. In the future, when this source is exhausted, new requirements will have to be met out of the proposed new hydroelectric plants on the Colorado, upstream from Hoover Dam, or by the construction of thermoelectric plants in the vicinity of Henderson.

Chlorates and Perchlorates

Sodium chlorate has been used extensively for many years in the U. S. and, particularly, in the western states for weed control along the right-of-way of railroads, highways, and power transmission lines. Potassium chlorate is used principally in the manufacture of matches and, to a lesser extent, in fireworks and in small arms ammunition.

Prior to World War II, the U. S. had been dependent to a large extent for these chemicals on imports from France and Germany. In 1938, there was only one domestic producer, located in New York state. Within the next few years, a number of plants were built, probably in anticipation that supplies to the match industry would be cut off by the impending war in Europe. Plants were built in various parts of the country—in California, New York, Oregon, Ohio, New Mexico, and Oklahoma. Several small plants sprang up in Los Angeles, each with a production capacity of potassium chlorate in the range of 10 to 60 tons per month. Western Electrochemical Company started operating in July 1941, and was the first commercial electrochemical chlorate operation in the western states.

High prices caused by the world shortage of chlorates made it possible for the small plants in this area to continue in operation for a few years. Prices soon dropped, however, as the supply grew and all of the small plants were gradually forced to shut down.



Aerial photograph of Hoover Dam

Western Electrochemical Company, meanwhile, had started production of sodium chlorate and potassium and ammonium perchlorates, as well as other special perchlorates for use as oxidizers in solid propellant for rockets of various types. The demand for potassium perchlorate and, to a lesser extent, for ammonium perchlorate developed rapidly. In order to meet at least a part of this new demand, Western Electrochemical Company started construction of a plant for the Defense Plant Corporation in Los Angeles. The plant was put into operation in January 1944, and later that year was expanded to 200 tons per month, just twice its original capacity.

Early in 1945, Western Electrochemical Company started construction of a much larger perchlorate plant

at Henderson, Nevada, for the Defense Plant Corporation. In November 1944, the Defense Plant Corporation's magnesium plant at Henderson was shut down, rendering these excellent facilities available for adaptation and installation of special equipment required for the manufacture of perchlorates. Arrangements were made to remove the magnesium-cell lines, and to install Schumacher chlorate and perchlorate cells and related equipment required for the production of perchlorates. It was thus possible, through the adaptation and use of existing buildings, transformers, and rectifying equipment, to furnish facilities within less than six months for the production of 1200 tons per month of potassium perchlorate. This plant was put into operation in July 1945, and, in a little more than a month, was shut down the day after V-J Day, when a clean-up program was initiated to put the plant in stand-by condition.

Meanwhile, operations were continued in the Los Angeles plant, and plans were made to convert it to peace-time use. Some rearrangement was necessary to begin to produce sodium chlorate and potassium chlorate, as well as potassium perchlorate. Outlets for these products were developed in the export market, and, by the end of 1945, sufficient demand existed to warrant the shutdown of the Los Angeles plant and the reactivation of the plant at Henderson. Under a lease arrangement with the Government, Western Electrochemical Company put the Henderson plant back into operation in February 1946. The Los Angeles chlorate-perchlorate plant was declared surplus by the Defense Plant Corporation, and the equipment was eventually dismantled and sold.

The perchlorate plant at Henderson was modified in a manner similar to the Los Angeles plant to make possible the production of sodium chlorate, potassium chlorate, potassium perchlorate, and ammonium perchlorate. Although the perchlorate market had been almost completely eliminated, sales of chlorates made possible the continued operation of the plant at a relatively high load factor. The use of potassium and ammonium perchlorate has grown steadily since that time, and, in 1951, due in part to the needs created by the Korean war situation, it again became necessary to expand the perchlorate facilities at Henderson.

New uses for chlorates, such as in the field of defoliants, particularly for cotton; in the manufacture of chlorine dioxide for bleaching of wood-pulp textiles; continued high demand for potassium chlorate in the manufacture of matches; and the growing demand for perchlorates in the field of solid propellants indicates that the market should remain firm for some time to come, or possibly grow to even greater proportions.

Chlorine and Caustic

The magnesium-producing facilities built at Henderson, for the Defense Plant Corporation during World War II included a chlorine and caustic plant. The purpose was to furnish make-up chlorine for the production of anhydrous magnesium chloride.

These facilities consist of two cell buildings, each containing 3 circuits of 150 Hooker Type S cells. Capacity of the plant was rated at 200-plus tons of chlorine and the equivalent amount of caustic per day. Direct current is supplied through six Allis Chalmers single-tank, multiple-anode rectifiers. The plant also includes facilities for evaporation of caustic solution, chlorine liquefaction, and utilization of by-product hydrogen as a fuel supplement in the generation of steam. Magnesium production was discontinued in November 1944, but because of other outside war demands for chlorine and caustic, this plant was kept in operation by Basic Magnesium, Inc., until in May 1945, when Stauffer Chemical Company took over the operation under a lease from Defense Plant Corporation (3).

Prior to 1940, Stauffer had developed a market in Southern California for caustic soda manufactured by their lime-soda process plant at Dominquez, California, but had no great market for chlorine. However, several users of chlorine were attracted to Henderson, and chlorine is now used by Stauffer for the manufacture of benzene hexachloride and hydrochloric acid.

Montrose Chemical Corporation of California uses chlorine in its plant located adjacent to the Stauffer chlorine plant for the manufacture of chloral and monchlorobenzene. These products are shipped from Henderson to Torrance, California, where Montrose uses them in the manufacture of DDT. Titanium Metals Corporation, also located at Henderson, uses some chlorine in the process of manufacture of titanium metal. Both by-product hydrochloric acid and the synthetic grade, produced by combining chlorine and by-product hydrogen, are used at Henderson by the various manufacturers located there. This new, on-the-spot chlorine market, together with the Los Angeles, Salt Lake City, and San Francisco markets for chlorine and caustic, has permitted continued operation of the plant.

In 1942, a small chlorine plant was put into operation by Ray-O Chemical Company, a subsidiary of Purex Corporation at South Gate, California. The plant is reported to have had a capacity of 5 tons per day, and consisted principally of electrolytic cells of the Vorce type and related facilities for the production of sodium hypochlorite bleach and chloride-of-lime bleaching powder. The plant was shut down in 1944 and has since been dismantled.

Manganese Dioxide

The occurrence of an abundant supply of low-grade manganese ores in the Southern California-Nevada area and in the bordering areas of Utah and Arizona, and the availability of existing facilities at Henderson led to the launching in 1949 of a development project to establish a plant for the manufacture of synthetic manganese dioxide.

The U. S. Army Signal Corps, as a result of encouraging findings of some research programs it had sponsored, was looking for someone to develop a commercial process for the manufacture of synthetic, battery-active manganese dioxide. It was anticipated that the United

States could become independent of foreign sources of supply of manganese dioxide, and also that better batteries could be produced, if an adequate supply of electrolytic manganese dioxide of consistently high quality were made available to the battery industry.

Manganese dioxide occurs naturally in various allotropic forms, not all of which are sufficiently active or chemically pure to be of interest to the battery manufacturers. Our national requirements for so-called battery manganese are supplied to a great extent from the ore deposits in the African Gold Coast region, probably because this is the only sizable known deposit of commercial quality.

Huge generators in the Nevada wing of the Hoover power plant

It has been known for some time that electrolytic battery-active manganese dioxide is superior in quality to the available natural ores when evaluated according to the Signal Corps Specification SCL-3117-D tests. Production of electrolytic battery-active MnO_2 began in the U. S. in the early 1930's, and it was first used in special battery applications where better than normal performance was required, or a reduction in weight was desired. In 1950, the output of three known producers was estimated to be 1100 tons, or about 2 per cent of the national requirements for battery manganese. Production was not expanded beyond this rate, probably because no practicable method had been found to produce a high quality product at a reasonable cost.

High-grade, imported oxide ores have been used as a source of manganese in the manufacture of electrolytic MnO_2 for the most part, although one producer used Montana rhodochrosite for a period of time, and later experimented with oxide ores from Georgia. It has been reported that, for economic reasons, all of the other present manufacturers are using an imported, high-grade, oxide ore as raw material.

Military demands for more and better batteries and the uncertainty of the important African supply, especially in time of war, pointed up the need for increased production of electrolytic MnO_2 from domestic ores.

Western Electrochemical Company was awarded a contract by the Signal Corps to develop a commercial process, and small-scale production began at Los Angeles in July 1950. Construction of a pilot plant was started at Henderson, in November 1950, and was put into operation in February 1951. Construction of a 10-ton-per-day plant was completed in May 1953. Facilities are available for further expansion, and it is anticipated that the plant will be expanded as required to meet the demands of both the military and civilian markets. The Signal Corps furnished all of the supplementary facilities required to effect the expansion.

Manganese Metal

Western Electrochemical Company started production of manganese metal in June 1953 on a development basis. Production is expected to expand gradually over a period of time to meet demands.

Titanium Metal

In 1951, Titanium Metals Corporation of America acquired approximately one-third of the Basic Magnesium facilities for the production of titanium metal by a modified Kroll process.

This was a logical location for a titanium plant since the by-product magnesium chloride from the magnesium reduction process could be regenerated into magnesium and chlorine in existing facilities.

Operating statistics on this plant are not available.

Ferromanganese

Pioche Manganese Company, an associate company of Combined Metals Reduction Company of Salt Lake City, acquired its part of the former Basic Magnesium facilities for the production of ferromanganese.

Manganese ore is mined by Combined Metals Reduction Company at Pioche, Nevada, and then beneficiated at their Caselton, Nevada, concentrator. The concentrates are converted into nodules suitable for feeding to an electric furnace in a kiln constructed by Pioche Manganese at Caselton.

The facilities acquired at Henderson have been extensively modified to accommodate the installation of two 7500-kva Pittsburgh Lectromelt furnaces and accessory equipment required to produce ferromanganese by the electrosmelting of the nodules and metallurgical coke. Production of ferromanganese is planned to begin in 1953.

This is the first electrosmelting operation in the area and is, therefore, a significant addition to the industrial

family at Henderson that may point the way for the utilization of other mineral raw materials in the area.

Aluminum

Aluminum Company of America built a reduction plant for the Defense Plant Corporation at Torrance, California. Construction was started in 1941 and the plant was put into operation in July 1942. Four pot lines were constructed and a fifth line was planned. Provisions were made for a connected load of 196,000 kw. Actually, there were never more than three lines in operation, and the plant was shut down in November 1944. The aluminum-making equipment has all been dismantled and the buildings have been put to other use. The plant was shut down apparently because the World War II quotas were being met by plants more suitably located with respect to low-cost power.

The vast postwar increase in population, home building, and industrial activity quickly absorbed the available surplus energy from Hoover Dam, and it became necessary for the City of Los Angeles and the Southern California Edison Company to build thermoelectric generating plants to supply the demand.

It appears unlikely at this time that this area, which is a large consumer of aluminum in many forms for use in the aircraft and allied industries, will ever again have an aluminum reduction plant. The recent expansion of the aluminum-producing industry brought new investigations of this area as a possible site for a reduction plant, but other sites were selected as being more suitable for the purpose, due principally to availability of lower-cost hydroelectric power.

Electrothermic Operations

A recent survey shows that there are now approximately 52 active, arc-type electric furnaces in the Southern California-Nevada area, including the Pioche Manganese furnaces at Henderson, comprising an estimated electrical demand load of 130,000 kw. The electrothermic demand load in 1940 is estimated at 20,000 kw. A large part of this remarkable increase has taken place in the postwar period. These furnaces range in size from 10-lb laboratory units up to the 75-ton units installed in the Bethlehem Pacific Coast Steel Corporation's Vernon, California, plant. Bethlehem installed two 75-ton Pittsburgh Lectromelt units and a 50-ton unit to increase capacity and to replace three gas-fired, open-hearth furnaces. The three electric furnaces are charged with cold scrap, as were the gas-fired, open hearths. Largest of the Bethlehem furnaces has a rating of 25,000 kva. It is now reported that another steel plant is planning to install two 25,000-kva units.

In addition to the arc-type furnaces, there are a large number of Ajax high-frequency induction furnaces used principally in melting nonferrous alloys.

Conclusions

Loss of the aluminum and magnesium industries was a real blow to the electrochemical industry of this area, but it was also a blessing, for it released an important block of electric power. The availability of the combination of a large block of low-cost power and large, unusually pliant facilities at Henderson made possible the growth of a diversified and substantial electrochemical industry.

Indications are that the tools of industrial electrochemistry will come into play even more in the Southern California-Nevada area as the world reserves of high-grade ores are depleted and as the use of the metals and materials that are difficult to unlock from their ores increases.

The aluminum industry, and possibly others that require very large quantities of power at very low cost, will probably not locate here again as long as there are undeveloped, potentially low-cost power sites available elsewhere.

The prospect of more hydroelectric-power development in the lower Colorado, the present industrial stability based on a diversity of new products and a hard won experience, and the abundance of important mineral raw materials in the immediate area, together point to more development for the electroprocess industries in this area.

Electric Power Development

Electric power is generated in the Southern California-Nevada area principally by the Southern California Edison Company and the Department of Water and Power of the City of Los Angeles; also by the municipal systems of Glendale, Burbank, and Pasadena; the San Diego Gas and Electric Corporation, and the California Electric Corporation.

One of the earliest Southern California hydroelectric projects was established at Highgrove in 1886 and served to light the streets of Riverside. Two other hydroelectric developments were the San Antonio Light and Power Company's Pomona plant, built in 1892, and the Redlands Electric Light and Power Company's Mill Creek Plant No. 1, in 1893. The latter was the first hydroelectric 3-phase plant in the United States. The Mill Creek Plant No. 1 is still in daily operation as a part of the Southern California Edison Company's far-flung hydroelectric system. Early thermoelectric plant installations in Southern California included the West Side Lighting Company, built in 1896.

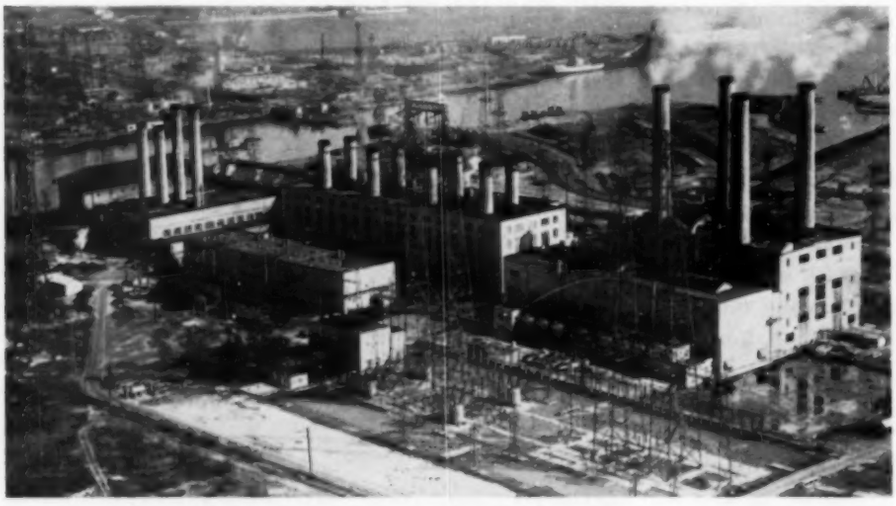
The first applications of the long-distance transmission of electrical energy at high voltages occurred in Southern California. Some of the notable dates of technical progress of the Southern California Edison Company in this respect are the first transmission of energy at 10,000 volts (San Antonio plant to Pomona and San Bernardino, 1892); at 33,000 volts (Santa Ana Canyon to Los Angeles line, 1899); at 45,000 volts (Kern River-Borel to Los Angeles line, 1904); at 60,000 volts (Kern River No. 1 to Los Angeles line, 1907); at 150,000 volts (Big Creek line, 1913); and the raising of the voltage of these lines from Big Creek to Los Angeles up to 220,000 volts in 1923. In 1936, the Department of Water and Power of the City of Los Angeles put into service a 266-mile transmission line

of 287,500 volts, the highest-voltage transmission line ever built up to that time. This line delivers Hoover Dam's power to Los Angeles.

The Southern California Edison Company

The Southern California Edison Company supplies electrical service to all or part of each of ten southern and central counties of California. The Company operates 25 hydroelectric plants having a combined operating capacity of 1,068,430 kw, four steam plants, and one internal combustion plant with combined capacity of 718,750 kw. Total generating capacity thus available for serving Edison customers is 1,787,180 kw. An additional 200,000 kw thermoelectric plant is under construction and will come into operation this year.

The largest hydroelectric development of the company is in the Sierra Nevada mountains of Fresno County, on the headwaters of the San Joaquin River, and consists of five plants. The Edison Company also



The Long Beach steam station of the Southern California Edison Company.

shares in the output of Hoover Dam. From 1939 until 1946, the company increased its use of the facilities at Hoover Dam, and, at the present time, an operating capacity of 465,000 kw at this plant is assimilated into the Edison system. Other hydroelectric developments are located in Tulare, Kern, Los Angeles, and San Bernardino counties. In connection with its hydroelectric plants, the company owns and operates three large reservoirs and four smaller ones for storage purposes and for regulation of the flow of the streams upon which the developments are located. The combined capacity of the three large reservoirs, Florence, Huntington, and Shaver Lakes in the High Sierras, is 288,855 acre-feet.

The thermoelectric station, located on Terminal Island, Long Beach, with generating capacity of 464,000 kw is one of the largest in the United States. The Redondo Beach Steam Station, one of the most modern installations of its type in the world, is now operating at full capacity of 264,000 kw.

For the transmission and distribution of electric energy, the Edison Company operates 3,870 circuit miles of high-tension transmission line and 15,800 miles of distribution line. The company also has 5000 circuit miles of private telephone lines, serving approximately 3200 telephones for organization use.

Los Angeles Department of Water and Power

The City of Los Angeles' municipally owned power system had its inception in 1908 in the construction of the Owens River Aqueduct. The aqueduct was built to bring water 250 miles to Low Angeles from the snow-capped High Sierras of the Owens Valley, but it also provided the opportunity to develop hydroelectric facilities along the route. Six generating plants were built during the period 1915 to 1932; two in San Francisquito Canyon, and one each at Franklin Canyon, Big Pine, Haiwee, and San Fernando. The generating capacity of the six plants totaled 105,400 kw. During the period 1932 to 1942, 455,000 kw were added to the City's generating capacity when Hoover Dam power plant was completed.

In 1937, the City of Los Angeles purchased the electric system of the Los Angeles Gas and Electric Corporation. The purchase added the Alameda and Seal Beach thermoelectric generating plants, providing a much needed stand-by capacity of 135,144 kw.

As a result of the advent of Hoover Dam power, the total generating capacity of the Southern California area in 1940 was 1,970,000 kw of which 60 per cent was hydroelectric power and 40 per cent thermoelectric power. However, of the total electric energy production in Southern California in that year, 92 per cent was generated by hydroelectric plants and only 8 per cent by steam-electric plants, indicating that a large surplus was available.

In order to help dispose of the surplus and, at the same time, stimulate new industry in the area, attractive rates for industrial power were established. Among these was an electrochemical rate of 2 mills in the lowest block, which enabled a plant with a demand of 700 kw and 700 hours of use per month to purchase power at an average rate of approximately 3 mills per kwhr. As a result, notwithstanding the existence of a depression, the sales of kilowatt hours increased

at a rate of approximately 200 million kwhr per year in Southern California between 1936 and 1940. Commercial and industrial power sales in Los Angeles City alone increased at the rate of approximately 20 million kwhr per year during the same period.

The Harbor Steam plant was completed in 1949. This plant consisted of five 65,000-kw units, which added a total of 325,000 kw to the system.

The Owens River Gorge hydroelectric project was started in 1949, and the first two of three plants to be constructed, each with a generating capacity of 37,500 kw, were placed in operation in 1952. The energy is delivered to a new 230-kv transmission line extending 260 miles to Los Angeles.

Construction was started in 1951 on the City of Los Angeles' largest generating plant. This steam-electric plant will have an ultimate capacity of 512,000 kw.

From 1900 to 1953, the population of the Southern California-Nevada area increased from about 380,000 to about 6,500,000. The power-generating capacity increased from a few thousand kw to 3,510,000 kw during the same period.

The phenomenal growth of population and industry was possible only by importing water and power from distant sources. The ever-growing demand for water and power led to construction of the Los Angeles-Owens Valley aqueduct and its power plants, and the Kern and San Joaquin power plants. It also was a great factor in bringing about the construction of Hoover, Davis, and Parker dams in the Colorado River.

Boulder Canyon Project and Hoover Dam

The Colorado River Compact, signed by the seven basin states in 1922, apportions the waters of the Colorado River system between the Upper and Lower Basins. Lee Ferry, Arizona, a few miles below the Utah-Arizona border, is the designated point of demarcation. Each of the basins is apportioned 7,500,000 acre-ft annually, while the Lower Basin has the right to increase usage by 1,000,000 acre-ft annually. This division does not apportion the total annual water yield of the system, but establishes the basis for supplying any right later recognized in Mexico (a treaty with Mexico went into effect November 8, 1945), and leaves the apportionment of any excess among the states to any time after October 1, 1963. The states of the Upper Basin cannot deplete the flow of the Colorado River at Lee Ferry below an aggregate of 75,000,000 acre-ft for any period of ten consecutive years.

The Boulder Canyon Project Act became a law on December 21, 1928, and was declared effective by President Herbert Hoover on June 25, 1929. The act authorized a total appropriation of $165,000,000 for the dam and the various other features involved. The purposes of the project are (*a*) flood control; (*b*) storage of water for irrigation; and (*c*) development of electrical energy for domestic and industrial purposes. The project is self-liquidating, largely through contracts for disposal of electrical energy. Construction was begun in 1931, and the dam was dedicated on September 30, 1935, by President Franklin D. Roosevelt. The first powerhouse generator was in full operation on October 22, 1936. On April 30, 1947, the Congress enacted Public Law 43, which officially designated the structure Hoover Dam.

Water Supply

The Colorado River rises in the Rocky Mountains of north central Colorado and flows 1400 miles southwest to empty into the Gulf of Mexico. Its basin comprises 244,000 square miles in the U. S. and Mexico, and its tributaries extend into the seven western states of Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming. Ninety-nine per cent of the basin is in the U. S. The watershed of the Colorado River and its larger tributaries above Hoover Dam—the Green, San Juan, Virgin, and Little Colorado rivers—comprises 167,800 square miles and includes portions of all of the Basin states except California. The Green River flows into the Colorado from the north through the canyons of Wyoming, Colorado, and Utah. The San Juan River, emptying into the Colorado from the east, drains mountain slopes and plateaus in southwestern Colorado, northwestern New Mexico, northern Arizona, and southeastern Utah. The Virgin River flows across the southwestern corner of Utah, the northwestern corner of Arizona, and discharges into Lake Mead in southeastern Nevada. The Little Colorado River rises in the White Mountains of east central Arizona and flows generally northwestward to join the Colorado in the upper reaches of the Grand Canyon.

Hoover Dam, designed and constructed by the Bureau of Reclamation, is located on the Nevada-Arizona boundary in Black Canyon. The dam is a concrete, arch-gravity structure with a maximum height of 726.4 ft, making it the highest dam in the world. The crest length is 1244 ft, the crest thickness is 45 ft, and the base thickness is 660 ft. The dam, power-plant building, and the appurtenances are owned, operated, and maintained by the U. S. Government. The generating facilities, also owned by the Federal Government, are operated and maintained by the City of Los Angeles' Department of Water and Power and Southern California Edison Company as agents for the Government. The Department of Water and Power of the City of Los Angeles is the generating agency for the states of Nevada and Arizona, the Metropolitan Water Districts of Southern California, and the municipalities of Los Angeles, Burbank, Glendale, and Pasadena; the Southern California Edison Company is generating agent for the private utilities.

The Hoover Dam power plant consists of two wings, one on each side of the river channel, with a connecting structure built along the downstream edge of the dam. The central part of the building houses the offices, shops, and control and storage rooms. The generating-plant equipment is installed in the wings, each of which is 650 ft long, about 120 ft in maximum width, 110 ft high above normal tailwater surface, and about 230 ft above the lowest part of the foundation. The possible maximum operating head is 590 ft; actually, the operat-

ing head varies seasonally according to reservoir water-surface elevation.

Installations in the power plant total 14 generators rated 82,500 kw, one 40,000-kw unit, one 50,000-kw unit, and two 2400-kw station service units. These generators provide a combined capacity of 1,249,800 kw, and are driven by turbines totaling 1,742,000 hp. Space is available in the Nevada wing of the plant for an additional 82,500-kw unit.

The U. S. has executed contracts for disposal of all of the firm and secondary energy generated at the plant until 1987. The generating agents were obligated to pay for such firm energy not used by the other allottees on the basis of one-half by the City of Los Angeles and one-half by the Southern California Edison Company. The allocation of the firm energy was as follows:

	per cent
State of Nevada	18
State of Arizona	18
Metropolitan Water Districts of Southern California	36
Municipalities, including City of Los Angeles	19
Southern California Edison Company and other private utilities	9

It should be noted that the allotments of firm power to the states of Nevada and Arizona and to the Metropolitan Water District made up 72 per cent of the firm power available; and since, at the time power was ready for delivery, these agencies had no use for it, large blocks of surplus power were available for Southern California. As a result, the City of Los Angeles agreed to suspend construction of a large steam plant and contracted with the Southern California Edison Company to lease part of its steam generating facilities for standby and auxiliary purposes.

New generators will allow a firm energy output of more than 4 billion kwhr annually, and it is estimated that an annual average of 750 million kwhr of secondary energy will be produced until 1987.

The Power Transmission System transmits energy from Hoover Dam to load centers in Arizona, Southern California, and Nevada. Privately owned lines transmit Hoover energy to the Los Angeles area of Southern California, and the city of Las Vegas and Lincoln County in Nevada. Energy allocated to Arizona and part of Nevada's allocation are transmitted under agreements with the states to the load centers on the Bureau's Parker-Davis Project transmission system. The Bureau of Reclamation has built high-voltage lines to interconnect Hoover power plant with Davis and Parker power plants to insure maximum utilization of the Colorado River water for power generation in the three plants.

The All-American Canal System was also authorized by the Boulder Canyon Project Act of 1928, which carried provisions for the construction of a highline canal, together with a diversion dam and desilting works, to be located entirely within the U. S., and to deliver Colorado River water to the Imperial and Coachella valleys in Southern California. Installations include Imperial Dam and desilting works on the Colorado River 303 miles below Hoover, the All-American Canal proper, its major branch the Coachella Main Canal, control structures, pumping plants, laterals, and a complete underground concrete pipe irrigation system. The 80-mile-long, All-American Canal, running just north of the Mexican border, was begun in 1934 and was practically completed in 1940. It was supplying water to Imperial Valley farm lands by 1941. The 123-mile Coachella Main Canal was substantially completed in June 1948.

Lake Mead, the reservoir behind Hoover Dam, has a storage capacity of 29,827,000 acre-ft, of which 9,500,000 acre-ft are reserved primarily for flood control purposes, with incidental use for production of secondary power. Measured by volume, the reservoir is the world's largest man-made lake. Besides providing flood control for areas below the dam, it stores water for downstream irrigation and domestic use and for the generation of electrical energy. It extends 115 miles upstream, has a maximum width of 8 miles, and a maximum depth of 583 ft. It was named in honor of Dr. Elwood Mead, who was Commissioner of the Bureau of Reclamation when Hoover Dam was under construction.

Surveys indicate that the muddy Colorado River deposits about 105,000 acre-ft of sediment behind Hoover Dam each year. At the present rate, it would take almost 300 years to fill Lake Mead with sediment, according to Bureau of Reclamation estimates. Taking into account the increased compaction of the deposited sediment as additional layers are placed on top of earlier deposits, it is estimated that it will be about 450 years before all storage capacity of the lake would be lost.

Parker Dam

Parker Dam, located 155 miles below Hoover Dam on the Colorado River, was designed and constructed by the Federal Bureau of Reclamation with funds advanced by the Metropolitan Water District. The dam was constructed to provide a fore-bay and desilting basin for the 242-mile Colorado River aqueduct. The aqueduct was built simultaneously with the Dam by the Metropolitan Water District, to deliver water to the Los Angeles area and coastal region.

Parker Dam is a concrete arch structure with about two-thirds of its structural height below the river bed. Only 85 ft of its bulk protrudes above the roadway that crosses its top.

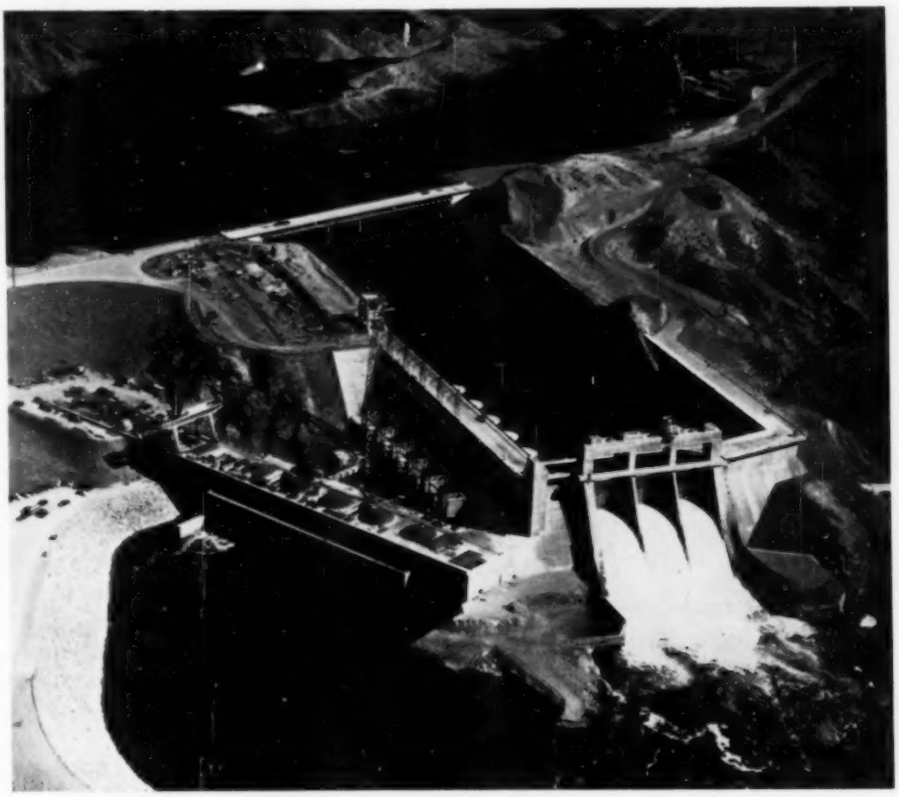
Havasu Lake backs up behind the dam for 45 miles and covers more than 24,000 acres. Total capacity of the reservoir is 716,000 acre-ft.

The Parker power plant includes four 30,000-kw generating units to make a total capacity of 120,000 kw. The power plant came into operation in December 1942. The power is allocated as follows: California, 56,250 kw, state of Nevada 56,250 kw, and the state of Arizona 112,500 kw.

Davis Dam

Davis Dam and power plant are on the Colorado River in Pyramid Canyon, 67 river miles below Hoover Dam. The Dam is an earth and rock filled embankment with concrete spillway, intake structure, and power plant. It has a crest length of 1600 ft and a top width of 50 ft. Its reservoir, Lake Mohave, has a capacity of 1,820,000 acre-ft and extends the entire 67 miles upstream to the tailrace of the Hoover Dam power plant.

The power plant is a semi-outdoor type. It has five 45,000-kw generating units, making a total capacity of 225,000 kw. Near the power plant are the 230-kw switch yards which provide the take-off point for a system of transmission lines and substations that interconnect the Davis, Hoover, and Parker plants and extend to load centers in Southern California, Nevada, and Arizona. The power plant came into full operation in June 1951. The power is allocated as follows: 25 per cent to California agencies, 50 per cent to Arizona agencies, and 25 per cent to the state of Nevada.



Aerial photograph of Davis Dam and power plant on the Colorado River, 67 miles below Hoover Dam. The power plant's five 45,000-kw generators furnish about a billion kwhr of hydroelectric energy annually to southern California, southern Nevada, and Arizona.

The stability of the power supply in the Southern California-Nevada area is enhanced by the diversity of energy sources—oil, gas, and water power. The water power sources in themselves have a great element of diversity, for the Colorado River rises on the Continental Divide in the Rockies, a thousand miles east of the Sierras, the other source of hydro power. Each source of water has a separate precipitation pattern, and records indicate that water shortages do not occur at the same time in each watershed. While other areas of the U. S. have had to curtail power use at various times, such has never been the case in Southern California, except for a short period in 1921, before Hoover power, and before adequate steam generation had been built.

This area is part of the Pacific Southwest Power Interchange, consisting of the utilities of Northern California, Southern California, Nevada, and Arizona. This is said to be one of the best integrated organizations of its kind in the country, all joined in a transmission network extending throughout the length of California, with heavy trunk lines joining Hoover, Davis, and Parker power plants.

Generating capacity for the Southern California-Nevada area at the beginning of 1953 totals 3,900,000 kw, approximately one-half hydroelectric and one-half thermoelectric.

It is estimated by the California Public Utilities Commission that by 1970 the power requirements of California will increase 7 million kw over present capacity, of which 3,500,000 kw will be needed by the Southern California-Nevada area under discussion. Of this amount, not more than 2,000,000 kw will be available to California from hydroelectric sources of approximately 500,000 kw on the Kings River in Central California, and of California's share of a potential 2,800,000 kw on the Colorado River. It remains to be seen how much of this potential will be available to the Southern California-Nevada area.

The electric utilities of Southern California point out that additional thermal plants can be built to supply new market demands. It is further pointed out that because of the high percentage of low-cost hydro power making up their capacity, and because of Southern California's substantial oil and gas supplies, and the supply of coal in Utah, relatively low energy rates can

be maintained. Southern California's rates for general power purposes are now lower than in any of the major industrial cities of the nation. There are only a few areas in the country where gas, oil, and water power are in surplus, and rates for large blocks of energy are lower.

Acknowledgments

Information concerning the Colorado river power developments was taken from various publications of the Department of Interior. Much of the information concerning the Southern California Edison and the City of Los Angeles power developments was obtained from their respective publications. C. H. Dye and A. Waterson of the Department of Water and Power of the City of Los Angeles contributed valuable information regarding power development and use.

R. R. Lloyd of the U. S. Department of Interior, Bureau of Mines, contributed information regarding activities at the Boulder City experiment station; Fred D. Gibson of Western Electrochemical Company regarding the Basic Magnesium plant; R. P. Smith of Titanium Metals Corporation of America and R. W. Lottridge of Pioche Manganese Company regarding their respective operations.

B. M. Holt and V. B. Seeley rendered valuable assistance in the preparation of the article.

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2. R. H. Ramsey, *Chem. Met. Eng.*, **50,** 98, 115 (1943).
3. T. B. Gibson, *Chem. Eng.*, **54,** 132 (1947).

Feature Section

Utility Steam-Electric Stations—Summary of Development in the United States[1]

Louis Elliott[2]

This story has to do with the growth and development of steam power plants in the United States. The basis of the review is data relating to public utilities, which operate the largest part of electric-power installations in the country. Hydroelectric plants include roughly 25 per cent of the electric capability in stations generating energy for sale to the public, but only steam stations are considered here.

Elements essential to life and progress include, among other things: food—produced in large part from the soil; the air we breathe—more or less free, although sometimes polluted; fresh water—in generous supply in favored localities, but in short supply in many cities and regions; public transportation—originally supplied by animal power, and now by railways, automobiles, and airplanes; communication at a distance—effected by wire and wireless transmission; electric power and energy—for all purposes.

For a good many decades, technical progress in railway transportation was slow, but in recent years there have been good advances. Increases and improvements in motor cars are familiar to everyone. Communication and power industries, for a half-century and more, have been promoted largely by companies that have exercised enterprise and vigor, continually improving means and performance, and contributing in large measure to the material welfare of the present day.

Growth and improvement in the telephone industry has constituted a striking and important chapter in the development of the United States. Fortunately, the control of this industry has been in such hands that broad resources of science and technology have been utilized, and there have been continued improvement and introduction of facilities. The service has been rendered at reasonable cost, considering investment and other charges.

Similarly, since early in the century, the electric-power industry has been in the hands of men and companies who have been unwearying in the application of new principles, methods and equipment, and who, through the period of rapid growth, have made possible the rendering of that essential service at reasonable cost. Unlike the selling prices for products of industry in general, rates for services rendered in supply of electric energy, as well as in communication, are closely controlled by public bodies.

[1] The author of this paper is a leading authority on the design and operation of steam power plants; the JOURNAL is happy to present his able review of the subject to its readers.—Ed.

[2] Consulting Power Engineer, Ebasco Services Incorporated, New York, N. Y.

The electric-power and telephone industries present good examples of what private enterprise can accomplish. In the writer's opinion, there is no valid reason, in a free economy, for governmental bodies to construct thermal or hydroelectric power plants that can properly be built by private industry. As a general principle, there should be no expenditure of tax money for projects that can be carried out successfully by private capital.

The progress of the electric industry has received important contribution from the manufacturers, who have designed and supplied turbine generators, steam generators, and other equipment required for the rapid growth and improvement in power units and stations. The engineers of these manufacturers have worked closely with utility engineers, with the objective of producing generating equipment in larger sizes and for higher efficiencies, to meet the growing demands.

A brief review of electric-power development in this country will give some perspective, although the history might well fill a volume.

Steam-Station Development

The business of supplying electric service to the public began in this country with the operation of a little power plant in New York City, put into service in 1882 by Thomas Edison. The generators were very small, belt-driven by reciprocating engines. By 1900, installed capability in power stations selling electric energy to the public totaled about 1,000,000 kw; by 1920, the total was in excess of 10,000,000 kw; as of the present time, it is approaching 100,000,000 kw.

Major development of the public-utility power industry began 35 to 40 years ago. Annual increase in generating capability, for the country as a whole, has been averaging around 6 per cent, compounded annually, equivalent to a doubling of the total about every 12 years. The communication industry has grown even more rapidly than that. Such geometrical increases have meant the investment, year after year, of increasingly large amounts of capital, working for the moderate earnings permitted by public utility commissions and other regulatory bodies.

The steam turbine was introduced in this country in the early years of the century, superseding the engine, and by 1920 it was available in sizes up to about 20,000 kw. Advanced steam conditions at that time were of the magnitude of 350 psig (pounds per square inch gauge) and 700°F, at the throttle. While it had been common practice to use steam drive for power-station auxiliaries, by 1920 the so-called regenerative cycle was developing, with steam extracted from the turbine between stages for heating feed water. That

type of plant might produce a net kilowatt-hour for as little as 15,000 Btu, equivalent to a thermal efficiency of about 23 per cent.

From 1920 onward, there was continued increase in turbine size, in throttle pressure and temperature, in number of extraction points of turbine, and in size and efficiency of boilers supplying steam to the turbine. These advances were taken in many steps, which it is unnecessary to review here.

At present, maximum steam conditions in use are of the magnitude of 2400 psig and 1100°F, number of feed-water heaters has risen to six or more, and steam is frequently taken from the turbine and returned to the boiler for reheating before reintroduction in the turbine. Boiler efficiencies have increased to around 90 per cent, and a very large number of improvements in station design have been made. Instead of the 15,000 Btu per net kwhr cited for the 1920 plant, station efficiency may now approximate 9000 Btu per kwhr, or 38 per cent thermal efficiency.

Sixty-cycle, steam-turbine generators have increased in speed from 1200 to 1800 rpm, and to 3600 rpm; the last named is now the usual speed. As to size of 3600-rpm steam-turbine units, 50,000-kw units were obtainable in the late 1930's, 100,000-kw in the 1940's, and at the present time a single-shaft, turbine-generator with a capability of 250,000 kw is under construction. Cross-compound turbines are obtainable in almost any size desired.

A major advance has been accomplished in size and design of steam generators. Units turning out well over 1,000,000 lb of steam per hour are not uncommon, and it has become usual practice to provide but one boiler per turbine, even for the largest sizes.

An advanced type of steam-turbine generator is under order, to be designed for steam at 4500 psig—beyond what is known as the critical point, at which steam and water have the same density, with initial steam temperature at throttle of 1150°F, and two stages of reheat at somewhat lower temperatures. A unit of this kind may produce a kilowatt-hour for 8500 Btu, equivalent to a thermal efficiency of 40 per cent. There will, of course, be many problems to work out in applying steam conditions of the magnitudes cited. Among these will be the provision of feed pumps adequate for the pressures and volumes required; another will be the selection of steel alloys that will be safe, over long periods, for the very high temperatures to be encountered.

The future of the thermal station is difficult to predict. From one viewpoint, it may appear that the limit in efficiency is being approached, with the elevated pressures and temperatures above cited, with two stages of reheat, and with multiple extraction. There will, doubtless, be other combinations developed, perhaps working in the gas-turbine cycle in some way with the steam cycle.

This study does not include an analysis of investment costs for steam power plants. Such costs, per unit of capability, naturally rise with increasing price levels. There have, however, been important savings effected by economy in design, by utilization of large turbine units and steam generators, by use of one boiler per turbine, and by reduction in housing required.

Producing Low-Cost Energy

The progress reviewed has not been made simply for the joy of developing new equipment and processes. While the engineer does take great satisfaction in working out continued technical advances, the main moving force has been the desire to produce electric energy at the lowest cost compatible with reliable and otherwise good power service. That this effort has proved successful is evidenced by the fact that selling prices for electric energy have not been advanced as has been the case with prices for most products. Over a long period, they have, indeed, been progressively reduced, in spite of the great rise in cost levels. The advances, not only in equipment and plant design and operation, but in system planning and development, have made it possible to maintain electric rates at such a level as to promote consumption, and to permit introduction, of electric power in a myriad of processes and uses.

The study of a power system, leading to recommendations as to location and arrangement of generating stations, size and steam conditions of units, selection of fuel, layout of condensing system, and methods of transmission, takes into account such important elements as size of power load, annual growth, cost of fuel, and investment cost for plant and transmission. The objective of all this planning is to produce energy at the lowest cost consistent with good service.

The writer of this article has been engaged in steam-plant engineering for 50 years, and has seen the electric-power industry grow from infancy to its present size. The company with which he has been connected, for 40 years, has designed and built steam stations, and has under design and construction additional plants, which approach 13,000,000 kw in total capability. Through the period cited, it has, therefore, been

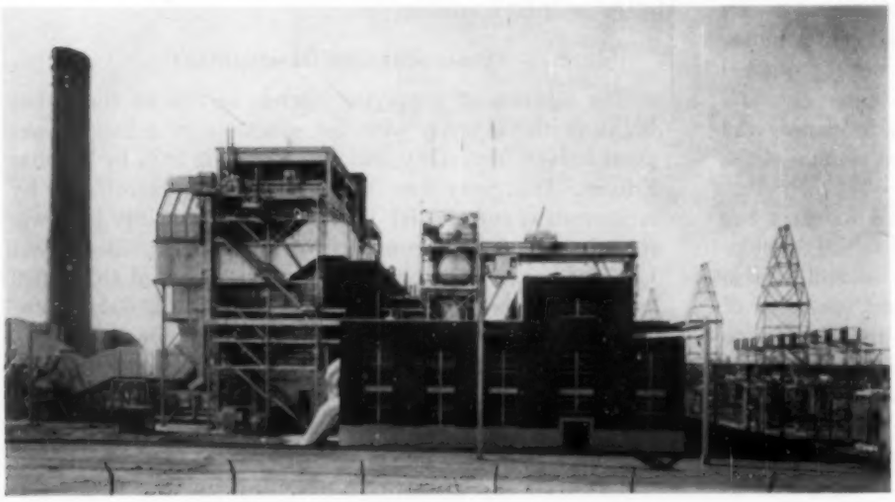

FIG. 1. Arkansas Power and Light Company — Electric steam station, 100,000 kw.

ossible to observe the growth and improvement of the industry, which has constituted a most interesting chapter in the development of the country as a whole

Outdoor-Type Designs

The working out of one feature of power-station design—not by any means the most important—may be cited as an example of progress. The writer's company has taken a large part in the development of the so-called outdoor or semi-outdoor station, planned with the idea of minimizing the cost of structures required for protection of machinery and operators. This development was started in the 1930's in relatively simple fashion; it has now progressed to the point of application to stations in operation, and under design and construction, numbering around 70, and incorporating something over 150 turbine units.

First and most obvious step in the development of these semi-outdoor plants is to place the steam boilers outdoors, housing—if considered desirable—the firing aisle and coal-preparation plant. Another step places the turbine on a deck, with a low housing over the machine, supplied with roof hatches or other means to permit assembly or dismantling of the machine by an overhead gantry crane. A third step omits the light structure over the turbine, sometimes providing a walk-in housing around the steam end of the turbine and one over the exciter, leaving the remainder of the machine outdoors. The savings obtainable by the semi-outdoor and outdoor designs, as compared with the conventional, fully housed type, may range from $3 per kw of station cost up to $10 or more.

Fig. 1 shows a 100,000-kw station, the units being enclosed in a low turbine room, with gantry overhead, and the boilers placed outdoors. Fig. 2 gives another example, a 135,000-kw station incorporating additional outdoor features; the two turbine units are placed on an open deck, with housing used chiefly for control room and service building. Both these plants have been in successful operation for a number of years. Plants of this type have been located as far north as Montana, Minnesota, and New York.

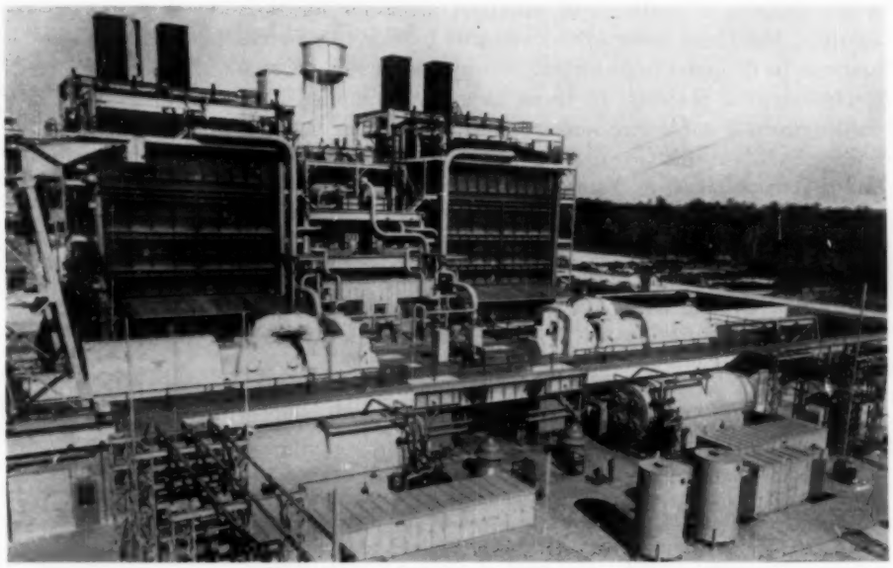

FIG. 2. Houston Lighting and Power Company — Electric steam station, 135,000 kw, outdoor type.

The power plants incorporating major outdoor elements, designed and built and under design and construction, aggregate roughly 10,000,000 kw in capability. The largest of the outdoor-type stations so far designed includes six units totaling 1,000,000 kw in capability. The first unit of this plant is in operation.

The operating periods for these outdoor stations have ranged up to 15 years, proving the practicability of the design. This particular feature of station design is mentioned here because of its unusual character, but that development, of course, constitutes only one item in the long list of improvements that have been introduced in the electric-power industry for the past 50 years. The advance goes on.

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Electrochemical Entomology

bug (bŭg) *n.* An insect of almost any kind. A defect in apparatus or its operation. (Webster's New International Dictionary, 2nd ed., 1945).

Because of the well-known law which states, in effect, that whenever it is possible for things to go wrong, they will do so; even chemical research and development are hardly to be classified as child's play. Occasional problems do arise which demand a modicum of skill and ingenuity for their solution, but these, once solved, offer no barrier to progress and can be dropped from further consideration. Not so with electrochemical projects! In these, as everyone knows, difficulties are not only more numerous to begin with, but also harder to eliminate, two rearing their ugly heads for every one that is disposed of. Strangely enough, it seems entirely to have been overlooked that a complete explanation of this paradox was published over a hundred years ago, in a paper[1] entitled, "On the production of Insects by Voltaic Electricity," by Andrew Crosse, Esq., &c, &c. Communicated in a letter from Sir Richard Phillips, to W. Sturgeon, Esq., &c. &c.

The author writes:

"I poured a dilute solution of silicate of potash, supersaturated with muriatic acid, into a quart basin standing on a piece of mahogany in a wedgwood funnel, and caused the fluid to fall . . . upon a piece of somewhat porous red oxide of iron from Vesuvius. . . Two platina wires at the opposite ends of the stone, were connected with the positive and negative poles of a voltaic battery, consisting of nineteen pairs of five-inch plates in cells filled with water and 1/500 muriatic acid. Thus the stone was kept constantly electrified by the battery, and moist by the dropping. At the end of fourteen days, two or three very minute white specks or nipples were visible on the surface of the stone, between the two wires, by means of a lens. On the eighteenth day these nipples elongated and were covered with fine filaments. On the twenty-second day their size and elongation increased, and on the twenty-sixth day each figure assumed the form of a perfect insect, standing on a few bristles which formed its tail. On the twenty-eighth day these insects moved their legs, and in the course of a few days more, detached themselves from the stone, and moved over its surface at pleasure . . . In the course of a few weeks more, about a hundred of these insects made their appearance on the stone . . . I ought to state that out of about a hundred insects, not above six or seven were born on the south side of the stone. I examined some of these insects with the microscope. Their shape was similar to that of the cheese mite, but they seemed to be from twice to eight times the size of that animalcule . . .

"They had in general eight legs, but there were some with only six; their bodies were covered with bristles which gave some of them the appearance of a little star; the length of the bristles at the tail was considerable, and these when highly magnified appeared spicated."

[1] A. Crosse, *Annals of Electricity*, **1**, 242 (1837). This was called to my attention and made available to me by Wilson Lynes, whose studies have already contributed so much to our knowledge of the early history of electrochemistry and corrosion (cf. *J. Electrochem. Soc.*, **98**, 3*C* (1951).

242 Mr. Crosse, *on the production of*

XLVI. ***On the production of Insects by Voltaic Electricity.*** ***By*** **Andrew Crosse, Esq.**, ***&c, &c. Communicated in a letter from*** **Sir Richard Phillips,** ***to*** **W. Sturgeon, Esq.** ***&c. &c.***

Dear Sir,

This morning I received the enclosed from Mr. Crosse, of Broomfield. Its contents are so novel and interesting that I am persuaded you will, even at this eleventh hour, give it place in your forthcoming number. With my best wishes for the success of your valuable Journal,

I am, respectfully,

Cadogan Place, R. PHILLIPS.
March 25th. 1837.

The following is the account of two experiments in which the birth of Insects was the unexpected result.

Broomfield, March 23d. 1837.

Dear Sir,

***Experiment* 1. I poured a dilute solution of silicate of potash, super-saturated with muriatic acid, into a quart basin standing on a piece of mahogany in a wedgwood [illegible] caused the fluid to fall by [illegible]**

The author went on not only to confirm his findings but also to extend his observations to other electrochemical systems:

". . . In the course of two or three weeks I had a second crop of insects upon the volcanic stone. I have also had two other formations in two distinct solutions of silicate of potash, also five others in the following solutions: 1, a weak solution of oxide of copper; 2, 3, 4, 5, in concentrated solutions of green sulphate of iron, sulphate of zinc, sulphate of copper, and nitrate of copper—in the whole, ten separate formations; five in silicious solutions, and five in solutions of metallic salts &c . . ."

As final and conclusive proof, Mr. Crosse bottled some thirty insects "produced in silicate of potash under the long-continued action of weak voltaic electricity" and sent them to Mr. E. M. Clarke, who offered "to show those insects to any person who is interested in the subject."

So now we know why it is so difficult to eliminate the bugs from an electrochemical process! For, added to the inherent stubbornness of soulless matter[2] which offers a deterrent to progress in all branches of physical science, the electrochemist must cope with the calculated malevolence of living entities (*Gubmuh Crossei* and var. *electrochemus*) which, formed by direct electrosynthesis, can multiply and fluorish *in situ*.

—G. W. H.

[2] "The total depravity of inanimate things." (Mrs. Edward Ashley Walker in *Atlantic Monthly*, Sept. 1864.)

Current Affairs

Program for the Wrightsville Beach Meeting

All arrangements have been completed for the Society's fall meeting at Wrightsville Beach, North Carolina, September 13–16. Committee meetings will be held on Sunday, September 13: Ways and Means Committee at 10 A.M., and the Board of Directors' meeting at 2 P.M. The formal opening of the convention will take place on Monday, September 14, at 9 A.M., with the start of the technical sessions.

The Ocean Terrace Hotel is headquarters for the meeting and most of the activities will be centered there, although some of the technical sessions will be held at the nearby Crest Theatre.

As Wrightsville Beach is about ten miles from Wilmington, North Carolina, arrangements have been made for special buses to meet the major trains to transport members from Wilmington to Wrightsville Beach. Also this community is on Eastern Standard Time. Consequently, all sessions and social functions are scheduled on E.S.T.

Members should consult their program booklets for details of social activities, committee meetings, divisional luncheons, etc. The Technical Program appears below.

Technical Program

Monday, September 14, 1953

9:00 A.M.—Formal Opening of 104th Convention, with Introduction by General Chairman F. L. LaQue, and response by President R. J. McKay.

Batteries

Monday, September 14, 1953

Round Table
Low Temperature Properties of Primary Cells

J. J. Coleman, Chairman

9:30 A.M.–12:00 M.—General Discussion.

Batteries (cont'd.)

Round Table
Positive Grid Corrosion

J. C. White, Chairman

2:00 P.M.–4:30 P.M.—General Discussion.

Corrosion

Tuesday, September 15, 1953

Fred W. Fink presiding

9:00 A.M.—"The Reaction of Nitrogen with, and the Diffusion of Nitrogen in, Beta Zirconium" by M. W. Mallett, Jack Belle, and B. B. Cleland, Battelle Memorial Institute, Columbus, Ohio.

9:25 A.M.—"The Reaction of Nitrogen with, and the Diffusion of Nitrogen in, Thorium" by A. F. Gerds and M. W. Mallett, Battelle Memorial Institute, Columbus, Ohio.

9:50 A.M.—"The Rate of Oxidation of Three Nickel-Chromium Heater Alloys between 500° and 900°C" by Earl A. Gulbransen and Kenneth F. Andrew, Westinghouse Research Laboratories, East Pittsburgh, Pa.

10:15 A.M.—"The Surface Reaction between Oxygen and Thorium" by A. F. Gerds and M. W. Mallett, Battelle Memorial Institute, Columbus, Ohio.

10:40 A.M.—"The Protective Action of Pigments on Steel" by M. J. Pryor, Division of Metallurgical Research, Kaiser Aluminum and Chemical Corporation, Spokane, Wash.

11:05 A.M.—"The Rate of Dissolution of Zinc in Chromic Chloride Solutions" by Cecil V. King and Natalie Mayer, Department of Chemistry, New York University, New York, N. Y.

11:30 A.M.—"Corrosion Studies Using the Rotogenerative Technique" by Howard T. Francis, Electrochemistry Research, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

Corrosion (cont'd.)

Fred W. Fink presiding

2:00 P.M.—"Kinetics of Surface Reactions of Metals, I. Iron" by Norman Hackerman and Donald M. Sowards, Department of Chemistry, The University of Texas, Austin, Tex.

2:25 P.M.—"The Tin-Steel Couple in Air-Free Citric Acid Solution" by E. L. Koehler, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

2:50 P.M.—"Corrosion Inhibition in Acid Solution" by Cecil V. King and Edward Hillner, Department of Chemistry, New York University, New York, N. Y.

Special Report on International Definitions

3:15 P.M.—"Remarks Concerning Electrochemical Conventions" by Pierre Van Rysselberghe, Department of Chemistry, University of Oregon, Eugene, Ore.

Palladium Medal Address

4:00 P.M.—"Coulometry—Related Phenomenon of Electrolysis and Current-Sweep Polarography" by N. H. Furman, Princeton University, Princeton, N. J.

Wednesday, September 16, 1953
Corrosion (cont'd.)

Fred W. Fink presiding

9:00 A.M.—"Kinetics of Reaction of Copper with Hydrogen Sulfide and Molten Sulfur" by A. Dravnieks and R. S. Neymark, Standard Oil Company (Indiana), Chicago, Ill.

9:25 A.M.—"The Reaction of Silver Alloys with Sulfur in Mineral Oils, II. Examination of Reaction Films and Mechanism of Reaction" by H. O. Spauschus, R. W. Hardt, and R. T. Foley, TAP Laboratory, General Electric Company, Pittsfield, Mass.

9:50 A.M.—"Mechanism of Reaction of Aluminum and Aluminum Alloys with Carbon Tetrachloride" by Milton Stern and Herbert H. Uhlig, Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

10:15 A.M.—"Anodic Behavior of Aluminum and Its Alloys in Sulfuric Acid Electrolytes" by Ralph B.

Mason and Phyllis E. Fowle, Aluminum Research Laboratories, New Kensington, Pa.

10:40 A.M.—"The Anodic Behavior of Pure Aluminum in H_2SO_4" by J. V. Petrocelli, The Patent Button Company, Waterbury, Conn.

11:05 A.M.—"Radioactive Tracers in the Study of Pitting Corrosion on Aluminum" by P. M. Aziz, Institute for the Study of Metals, University of Chicago, Chicago, Ill.

11:30 A.M.—"Studies on the Anodic Polarization of Zirconium and Its Alloys" by Mario Maraghini and Pierre Van Rysselberghe, Department of Chemistry, University of Oregon, Eugene, Ore.

Corrosion (cont'd.)

Fred W. Fink presiding

2:00 P.M.—"Galvanic Corrosion Behavior of Titanium and Zirconium in Sulfuric Acid Solutions" by David Schlain, Charles B. Kenahan, and Doris V. Steele, U. S. Department of the Interior, Bureau of Mines, College Park, Md.

2:25 P.M.—"Potentials of Iron, 18-8, and Titanium in Passivating Solutions" by Herbert H. Uhlig and Arthur Geary, Corrosion Laboratory, Department of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

2:50 P.M.—"Corrosion Properties of Titanium in Marine Environments" by G. E. Hutchinson and H. B. Bomberger, Rem-Cru Titanium, Inc., Midland, Pa.

3:15 P.M.—"Results of Some Marine Atmosphere Corrosion Tests on Magnesium-Lithium Alloys" by P. D. Frost, F. W. Fink, J. H. Jackson, and H. A. Pray, Battelle Memorial Institute, Columbus, Ohio.

3:40 P.M.—"Galvanic Currents in the Electrode System Magnesium-Steel-Copper in Sea Water" by Thomas P. May, Corrosion Engineering Section, Development and Research Division, The International Nickel Company, Inc., New York, N. Y., and R. B. Teel, The International Nickel Company, Inc., Marine Corrosion Testing Station, Harbor Island, N. C.

4:05 P.M.—"Jet Impingement Tests" by P. T. Gilbert, Corrosion Section, The British Non-Ferrous Metals Research Association, London, England, and F. L. LaQue, Corrosion Engineering Section, Development and Research Division, The International Nickel Company, Inc., New York, N. Y.

Electrodeposition

Monday, September 14, 1953

M. L. Holt presiding

9:30 A.M.—"Radiometric Study of the Chromium-Sulfate Complex Formed in Chromium Plating Baths" by Ronald L. Sass and Stanley L. Eisler, Radiochemistry Section, Ordnance Corps, Rock Island Arsenal Laboratory, Rock Island, Ill.

10:00 A.M.—"A Study of the Variables Affecting the Particle Size of Electrodeposited Lead Powder" by James B. Crownover and Charles L. Mantell, Department of Chemical Engineering, Newark College of Engineering, Newark, N. J.

10:30 A.M.—"Adherent Electroplating on Molybdenum" by Robert M. Hansen and Charles L. Mantell, Department of Chemical Engineering, Newark College of Engineering, Newark, N. J.

11:00 A.M.—"Polarization Studies of Copper, Nickel, Titanium, and Some Copper and Nickel Alloys in Salt Solutions" by H. B. Bomberger, Rem-Cru Titanium, Inc., Midland, Pa., and F. H. Beck and M. G. Fontana, Corrosion Research Laboratories, The Ohio State University, Columbus, Ohio.

11:30 A.M.—"Electrodeposition of Cellulose" by Charles L. Mantell and Frank Cozzarelli, Department of Chemical Engineering, Newark College of Engineering, Newark, N. J.

Electrodepositon (cont'd.)

C. A. Snavely presiding

2:00 P.M.—"Electrodeposition of Nickel-Molybdenum Alloys from Aqueous Solutions" by D. W. Ernst and M. L. Holt, Chemistry Department, University of Wisconsin, Madison, Wis.

2:20 P.M.—"Electrodeposition of Cobalt-Molybdenum Alloys from Aqueous Solutions" by R. F. Amlie and M. L. Holt, Chemistry Department, University of Wisconsin, Madison, Wis.

2:40 P.M.—"Electrodeposition of a Lead-Tin Alloy Containing Six Per Cent Tin" by William S. Fischgrund and Charles L. Mantell, Department of Chemical Engineering, Newark College of Engineering, Newark, N. J.

3:10 P.M.—"Periodic Current Reversal in Plating Copper-Lead Alloys" by Nelson W. Hovey, John L. Griffin, and Albertine Krohn, University of Toledo, Toledo, Ohio.

3:40 P.M.—"The Effect of Periodic Reverse Plating Variables on Density and Electrical Conductivity of Silver" by William H. Colner and Harold L. Schick, Armour Research Foundation of Illinois Institute of Technology, Chicago, Ill.

Tuesday, September 15, 1953

Electrodeposition (cont'd.)

M. L. Holt presiding

9:30 A.M.—"Electronic Configuration in Electrodeposition from Aqueous Solutions, II. The Deposition Process" by Ernest H. Lyons, Jr., The Principia College, Elsah, Ill.

10:00 A.M.—"Electronic Configuration in Electrodeposition from Aqueous Solutions, III. Deposition from Certain Metal Complexes" by Ernest H. Lyons, Jr., The Principia College, Elsah, Ill., and John C. Bailar, Jr., and Herbert A. Laitinen, University of Illinois, Urbana, Ill.

10:30 A.M.—"The Interaction of Organic Compounds with the Surface during the Electrodeposition of Nickel" by Clayton C. Roth and Henry Leidheiser, Jr., Virginia Institute for Scientific Research, Richmond, Va.

11:00 A.M.—"Role of Shape of Colloidal Molecules in Electrolytic Metal Deposition" by S. Levy, Perth Amboy, N. J.

11:30 A.M.—"The Theory of Transfer of Polarization in Codeposition of Metals" by Abner Brenner, National Bureau of Standards, Washington, D. C.

Electrothermics

Tuesday, September 15, 1953

I. E. Campbell presiding

9:00 A.M.—"Research and Development in the Field of Carbides, Nitrides, Silicides, Alumides, and Borides for Aircraft Propulsion: A Status Report" by L. D. Richardson, Ceramic Section, Matériels Laboratory, WADC, Wright-Patterson Air Base, Ohio.

9:30 A.M.—"Bonding in the So-Called Interstitial Compounds" by Alan W. Searcy, Department of Chemistry, Purdue University, Lafayette, Ind.

10:00 A.M.—"The Stability of Refractory Silicides and Their Reactivity with Carbon and Nitrogen" by Leo Brewer and Oscar L. Kikorian, University of California, Berkeley, Calif.

10:30 A.M.—"Fabrication and Properties of Hafnium Carbide" by L. M. Doney, Ceramic Group, Oak Ridge National Laboratory, Oak Ridge, Tenn.

11:00 A.M.—"The Preparation and Examination of Beryllium Carbide" by M. W. Mallett, E. A. Durbin, M. C. Udy, D. A. Vaughan, and E. J. Center, Battelle Memorial Institute, Columbus, Ohio.

11:30 A.M.—"Electric Sintering" by F. V. Lenel, Department of Metallurgical Engineering, Rensselaer Polytechnic Institute, Troy, N. Y.

Electrothermics (cont'd.)

Tuesday, September 15, 1953

Round Table

2:00 P.M.–4:30 P.M.—Round-table discussion "The Role of Electrothermics in the Preparation of Refractory Materials, Part I. Solid-Solid Reactions."

Pittsburgh Diffraction Conference, Nov. 5–6

The Eleventh Annual Pittsburgh Diffraction Conference will be held at Mellon Institute, Pittsburgh, Pennsylvania, on November 5–6, 1953. Technical sessions are being arranged on "Instrumentation and Methods," "Metals," "Recrystallization and Preferred Orientation," and "Structure of Polymers." Papers on general diffraction subjects will also be accepted.

Contributed papers will be considered in the order in which they are received. Titles should be submitted to the Program Chairman, Mr. E. E. Wicker, United States Steel Corporation, Research and Development Laboratory, 234 Atwood Street, Pittsburgh, Pa. before September 1, 1953. Abstracts should be submitted by September 21.

For further information, and for a copy of the preliminary program when available, write to Dr. H. R. Letner, Mellon Institute, Pittsburgh, Pa.

Marden Prize Winner Announced

Earl Ehresman has been awarded the John W. Marden Prize for 1953, based on outstanding scholastic achievement in chemical engineering.

The prize, consisting of a one-year subscription to the Journal of The Electrochemical Society, was established by John W. Marden, to be awarded annually to the outstanding student in Chemical Engineering at Illinoin Wesleyan University, Bloomington, Illinois.

Earl Ehresman was born near Gridley, Illinois, in 1924. Following graduation from the local high school, he joined the U. S. Navy, later attending James Millikin University. In 1951, he enrolled at Illinois Weslyan and will receive the B.S. degree from that institution this summer. He then plans to accept a position as an industrial chemist. He resides at Gridley, Illinois.

Scientific Committee to Study Tests on AD-X2

Following the recent announcement of the Senate Select Committee on Small Business that it would reopen hearings on the AD-X2 case, the National Academy of Sciences released the names of eight scientists who have agreed to serve on a committee to evaluate tests on the product made by the National Bureau of Standards. The Chairman of the committee, which was appointed by Detlev W. Bronk, prseident of the National Academy, is Zay Jeffries, retired vice-president in charge of the chemistry department, General Electric Company.

Those serving on the committee include J. C. Warner, president of Carnegie Institute of Technology and recent past-president of The Electrochemical Society; Victor K. LaMer, professor of chemistry at Columbia University and editor of the *Journal of Colloid Science*; John G. Kirkwood, professor of chemistry at Yale University; and Elmer K. Bolton, retired director of the chemical department, E. I. du Pont de Nemours & Co., Inc.

Other members of the committee are Lewis G. Longsworth, physical chemist with Rockefeller Institute for Medical Research; Joseph E. Mayer, professor of chemistry at the University of Chicago and recent editor of the *Journal of Chemical Physics*; and William G. Cochran, professor of biostatistics at Johns Hopkins University.

The Senate committee is proceeding with its hearings, regardless of the appointment of the scientific committee.

* * *

The committee appointed by the National Academy met on July 15 and 16, after considerable investigation on the evaluation of the fairness of tests run by the National Bureau of Standards on the battery additive AD-X2. The committee discussed their findings so far, interviewed interested persons, and listed additional needed information. Their next meeting is planned for September, when they hope to be able to reach a final conclusion, or decide whether additional tests will be required.

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Scholarship to Illinois Tech by Sherwin Williams

The establishment of a scholarship in chemical engineering at Illinois Institute of Technology, Chicago, by the Sherwin-Williams Company, Cleveland, Ohio, was recently announced by Ralph G. Owens, dean of engineering at Illinois.

Chemical engineering students who have completed three years of college work will be eligible for the award, based on scholastic record, general ability, and need for assistance. It amounts to $500 annually.

Cathodic Protection Course at U. of Illinois, Oct. 12

A Short Course on Cathodic Protection will be given at the University of Illinois, Urbana, Illinois, October 12–16. The National Association of Corrosion Engineers is cooperating with the university in presenting the course and all instructors are members of NACE. Professor Ray Wainwright of the university is coordinator.

The sessions will cover practical information useful to operating and engineering personnel. A college degree is not a prerequisite for registration, which is limited to 50 persons. Cost of the 5-day course is $47.50, payable to the university. Registration information may be obtained from Professor R. K. Newton, 713½ South Wright Street, Champaign, Illinois.

SECTION NEWS

Pittsburgh Section

The Pittsburgh Section held its annual informal Spring Symposium June 12, 1953, at the Alcoma Country Club. The day's program was as follows:

9:15 A.M.—Registration and informal get-together.

9:30 A.M.—Dr. Z. Shapiro, Research Scientist, Atomic Power Division, Westinghouse Electric Corp., "Preparation and Properties of Zirconium."

10:15 A.M.—Dr. Raymond Craig, Assoc. Professor, University of Pittsburgh, "Electrochemical Cell Studies on the Cadmium-Magnesium System."

11:00 A.M.—Dr. Fred Keller, Chief, Metallography Div., Aluminum Research Laboratories, "Oxide Films on Aluminum."

12:00 M.—Luncheon.

1:45 P.M.—Dr. C. Zener, Associate Director, Westinghouse Research Labs., "Thermodynamics of Rectifying Junctions."

2:30 P.M.—Dr. Henry Frank, Head, Chemistry Dept., University of Pittsburgh, "Structure and Properties of Aqueous Solutions."

3:30 P.M.—Section business meeting, followed by golf and social activity.

The interesting and enjoyable meeting was arranged by a committee composed of: E. K. Camp and E. A. Gulbransen—Westinghouse Research Laboratories, and R. D. Williams—Aluminum Research Laboratories.

R. A. WOOFTER, *Secretary-Treasurer*

India Section

The Annual Meeting of the Section was held on Wednesday, June 10, in the Council Hall, Indian Institute of Science, Bangalore. Chairman M. S. Thacker presided.

The meeting commenced with a warm welcome by Professor Thacker to the members present.

The Secretary-Treasurer read the minutes of the business meeting held on April 29, 1953, and they were unanimously approved.

The Secretary-Treasurer then presented the report of activities of the Section for the year 1952–53. The chairman expressed great satisfaction at the progress made by the Section during the year and the attention it has been receiving from different scientific circles, and desired the members to present their views. Members present associated themselves with the sentiments expressed by the chairman and assured wholehearted cooperation in the growth of the Section.

The decision at the last business meeting that the proceedings of the symposium on "Electrolytic Alkali-Chlorine" be published in the *Bulletin* was approved. The Chairman drew the attention of members to the need for enrollment of more members and Patrons to further strengthen the activities of the Section, and exhorted the members to do their utmost to make the Section a vital link in the electrochemical field in India.

The Executive Committee was requested to explore the possibility of arranging another symposium during 1954, either jointly with any other scientific society, or on its own.

The following resolution was unanimously passed:

"The India Section places on record the keen interest evinced by Sri. D. N. Hosali in the activities of the Section and the valuable assistance being received from The Hosali Press in the publication of the *Bulletin of the India Section.*"

The Secretary-Treasurer then informed the gathering that at the business meeting held on April 29, the report of the nominating committee was read, nominating the following officers for 1953–54. No further nominations have been received in response to the circular sent for the purpose:

Chairman—M. S. Thacker
Vice-Chairman—V. M. Dokras
S. Ramaswamy
Secretary-Treasurer—J. Balachandra

As no other nominations have been received, the chairman declared the above members duly elected.

The chairman thereupon nominated members of the various Committees (Vide Appendix I, page 2).

The dues of the Section for 1954 were fixed at Rs.2/8/.

The technical session was postponed to a later date considering the desirability of arranging it as a separate meeting in view of the importance of the subject matter of the talk.

The chairman thanked the members present for their cooperation in the activities of the Section. With a vote of thanks by the Secretary to the Chair, the meeting terminated and tea was served.

Committees

The following committees were appointed for 1953–1954:

Membership Committee:

B. K. Ram Prasad and K. Rajagopal.

Local Section Advisory Committee:

L. Charat Ram and K. Rajagopal.

Bulletin-Editorial Committee:

B. K. Ram Prasad, (Chairman); M. S. Thacker, *ex-officio*; S. Ramaswamy, *ex-officio*; J. Balachandra, *ex-officio*; V. M. Dokras, *ex-officio*; V. Aravamuthan, S. Krishnamurthy, T. L. Ramachar, (Editor).

Bulletin Advisory Board:

J. P. Kapur, K. L. Ramaswamy, R. S. Ramachandran, K. Seshadri, K. Raja-

Correction

In the regional article "The Pacific Northwest," June JOURNAL, page 146C, some incorrect figures appeared concerning Pennsylvania Salt Manufacturing Company's production of chlorine, caustic soda, and chlorates. These figures should read: chlorine, 75,000 tons/yr; caustic soda, 40,000 tons/yr; and chlorates, 8,000 tons/yr.

gopal, A. Joga Rao, B. Narayana Das, L. Jariwala, P. S. Narayana.

. BALACHANDRA, *Secretary-Treasurer*

G. W. Heise Retires

George W. Heise, Associate Director of the National Carbon Research Laboratories in Cleveland, Ohio, retired on June 30, 1953, after thirty-four years of association with this organization.

Mr. Heise is well known for his professional activities, and for his work on air-depolarized and other primary cells, electrochemical processes, catalytic and sorbent carbons, and water supplies. He, and coworkers, have contributed more than forty papers and over seventy patents to the literature in these fields.

Mr. Heise plans to continue an active interest in technical and professional affairs. He has long been an active member of The Electrochemical Society, of which he was president in 1947.

Support Our Advertisers

Since advertisers in the JOURNAL are investing money in our publication, members of the Society have a great opportunity to cooperate in the mutual success of the project. For instance, Society members buy large quantities of products, instruments, and equipment. Whenever an advertiser's products meet company specifications, readers are urged to give preference in their purchases to JOURNAL advertisers.

PERSONALS

JOHN C. R. KELLY, JR., has transferred to Westinghouse Electric Corporation, Pittsburgh, Pa., from the company's plant at Bloomfield, N. J.

NORMAN BAUER has joined the Chemistry Department, Utah State Agricultural College, Logan, Utah. Mr. Bauer was formerly co-director of Physical Science Associates, at Berkeley, Calif.

H. V. K. UDUPA has been appointed senior scientific officer at the Central Scientific Research Institute, Karaikudi, India, by the Government of India. Dr. Udupa studied in the U. S., receiving the M.A. degree from Columbia University, and the Ph.D. degree from Ohio State University in 1950. Since then he has been connected with the Ahmadabad Textile Industry's Association, in Ahmadabad, India.

STEPHEN HEBEL has been named factory superintendent by Electro Platers Company, Milwaukee, Wis. Mr. Hebel was formerly located in Calcutta, India.

ALAN KISSOCK, mining engineer, of Laurelton, N. J., has moved his office to 70 Pine Street, New York City.

WILLIAM G. HARVEY has retired from Aluminum Company of America and is at present residing at Roscommon, Mich.

CHRISTIAN H. AALL has been named director of development, from assistant director, for Monsanto Chemical Company's Phosphate Division in St. Louis, effective July 1.

HENRY S. WALKER, formerly of the Detroit Edison Company, Detroit, Mich., is now at Insto-Gas Corporation in Detroit.

GUSTAV DOBRIN has joined Span-O-Life Battery Manufacturing Company, New Braunfels, Texas. Mr. Dobrin had been with Perrine Quality Products Corporation, Waltham, Mass.

JAMES FENTRESS has recently been promoted to manager of Petroleum Sales for Foote Mineral Company, Philadelphia, Pa.

NEW MEMBERS

In July 1953, the following were elected to membership in The Electrochemical Society:

Active Members

GEOFFREY C. GAUT, The Plessey Company, Ltd., mailing add: Caswell, Towcester, Northants, England (Electric Insulation, Electronics, Electrothermic, and Industrial Electrolytic)

VE DELL E. GUERNSEY, Norbrook, Inc., mailing add: 2313 Columbia Rd., Berkley, Mich. (Electrodeposition)

ROBERT E. HOFFMAN, Radio Corporation of America, mailing add: R. D. #1, Ephrata, Pa. (Electronics)

JOHN S. HOUSTON, Major Appliance Laboratory, General Electric Co., 310 W. Liberty St., Louisville 2, Kentucky (Corrosion and Electrodeposition)

DOUGLAS J. KENNEDY, Shawinigan Chemicals Ltd., Shawinigan Falls, Quebec, Canada (Battery)

FRANK X. MCCAWLEY, Chicago Development Corporation, mailing add: 4301 Russell Ave., #3, Mt. Rainier, Md. (Battery)

A. H. ROEBUCK, Argonne National Lab., P.O. Box 299 Lemont, Ill. (Corrosion)

WATARU SAKAI, Dept. of Applied Chem., Faculty of Engineering, Kyushu University, Hakozaki-machi, Fukuoka City, Japan (Electrodeposition, Industrial Electrolytic, and Theoretical Electrochemistry)

JOHN F. SCHAEFER, Globe-Union Inc., 900 E. Keefe Ave., Milwaukee 1, Wis. (Battery)

HOWARD STOERTZ, The Electric Storage Battery Co., P.O. Box 5723, Philadelphia 20, Pa. (Battery and Corrosion)

JOHN F. WAYMOUTH, Sylvania Electric Products, Inc., mailing add: Masconomo St., Manchester, Mass. (Electronics)

Reinstatement

GEORGE C. COX, Colonel Retired, U. S. Army, Mailing add: 3711 Washington Ave., S.E., Charleston 4, W. Va. (Corrosion)

Highlights of the Board of Directors' Meeting

(Held July 10, 1953)

Present at the meeting were: R. J. McKay, M. J. Udy, H. H. Uhlig, E. G. Widell, J. C. Warner, R. M. Burns, F. W. Fink, R. H. Cherry, R. A. Ruscetta, E. Willihnganz, L. I. Gilbertson, W. H. Prine, H. R. Copson, H. B. Linford, W. J. Holian, and Mrs. R. G. Sterns.

The financial status of the Society was discussed in some detail. So far, the operations have been kept fairly well within the budgetary allotments. The principal deviation is the printing and mailing of the JOURNAL. However, this deficit is due to the double-size December 1952 issue. (The JOURNAL budget for a given calendar year includes costs of publishing the December issue of the previous year through the November issue of the current year.) This oversized JOURNAL, however, has paid large dividends in other ways, and it is to be considered a very desirable investment.

The proposed revised budget for the remainder of the year 1953 was then presented. The figures below record the budget as adopted in January 1953, and the revised figures based on the first six-months' operation.

* * *

The rent increase is a result of moving to new quarters at higher rentals. However, the rentals now being paid are not excessive in the light of the plans of our former landlord. After considering carefully each item, this proposed revised budget was approved.

At the April convention, the Secretary and Editor were requested to proceed, if possible, with publication of the monograph based on the Symposium on the Application of Electrochemistry to Biology and Medicine. The Secretary reported that the services of Dr. Theodore Shedlovsky of Rockefeller Institute have been obtained as Editor-in-Chief. He has selected his Advisory Committee as follows: Drs. L. R. Blinks, R. M. Burns, W. J. Hamer, H. H. Jasper, L. G. Longsworth, and D. A. MacInnes. The Secretary then asked for approval of action taken on advancing funds to Dr. Shedlovsky for secretarial assistance. This was a condition required by Dr. Shedlovsky before accepting the appointment as Editor-in-Chief, and to date the sum of $250 has already been advanced to get this job underway. After considerable discussion of this procedure, in the light of the manner proposed by the Secretary for handling such expenditures, namely, that monies so advanced will be returned to the general funds of the Society from the first royalties received from the monograph, it was voted by the Board that in the future the Secretary will be authorized to advance up to $600 for editor's assistance on any approved monograph.

Dr. Harry Copson, General Chairm of the recent New York Conventio made a financial report which, in su mary, resulted in a return to t national organization of $1,240. Th represented $2 per member and no member registered, and in additio $1,938.43, the remaining surplus fro the convention. Since the national o ganization underwrote the conventio these funds were turned over to gener income. The total return from th New York Convention amounted $3,178.43. Dr. Copson was given a vo of thanks by the Board for his and h committee's work.

The matter of vacation policy of th Society employees was reviewed, an the following agreement was the reached. All Society employees, with th exception of the Secretary, shoul operate under the following agreement Employees of less than five years' stand ing will receive two weeks' paid vacatio each year after completing one year service. After five years, the vacation i extended one day for each additiona year's service until ten years have bee reached, when the employee receive three weeks' vacation. This continue as three weeks' vacation from then on

The Secretary read a report from Mr Bain, our advertising representative, i which Mr. Bain pointed out that sinc the April Board meeting approximately $1,900 in new business has been added

PROPOSED REVISED BUDGET FOR 1953

Income

	Revised Estimated 1953	Adopted (Jan. 1953) Budget for 1953
Membership Dues	33000	33000
Sustaining Memberships	9000	9000
Sale of Publications:		
Back Transactions	2000	2000
Reprints and Preprints	2500	2500
Non-members Subs. Journal	16000	15000
Office Sale Journal	1500	1500
Modern Electroplating	50	50
Royalties "Cathodic Prot."	100	100
Convention Registration	3500	2000
Advertising	13996*	11878
Total	81646	77028

Expenditures

	Revised Estimated 1953	Adopted (Jan. 1953) Budget for 1953
Reprinting and Mailing Journal	26998*	26000
Reprints	2000	2000
Publication Committee	250	250
Advertising Commission	5200	5200
ABC Rating	300	300
Salaries	34000	33000
Rent	2010	1620
Postage, Supplies & Misc.	5500	4800
Travel	700	700
Auditor	175	175
Local Sections & Divisions	1000	1000
Prize to Young Authors	100	100
Program Booklets, etc.	1500	1500
Total	79733	76645

Summary

Income	81646	77028
Expenditures	79733	76645
Excess Income Over Expenditures	1913	383

* These items are to be increased as per agreement by Board of Directors, January 30, 1953 (See Expenditures also).

the JOURNAL. Mr. Bain further urgently requested the same type of assistance that he has received from Mr. McKay in connection with International Nickel Company, Dr. Musgrave in connection with Mallinckrodt Chemical Works, Dr. Thurnauer in connection with American Lava Corporation, and Dr. Uhlig at General Radio Company.

President McKay presented a request from Pierre Van Rysselberghe that The Electrochemical Society appoint an official representative to the forthcoming meeting of the International Committee on Electrochemical Thermodynamics and Kinetics. This problem was discussed at some length, resulting in the following motion being passed by the Board: The Society goes on record as not being in favor of appointing official representatives to regularly scheduled meetings of other societies.

The President then brought up a request that The Electrochemical Society help sponsor the new publication "Acta Metallurgica," now being sponsored by the American Society for Metals. This was discussed and referred to the Secretary and Editorial Committee for further study.

A letter was then read from Dr. Thurnauer indicating that he was on an extended tour of Europe and was therefore unable to attend this particular Board meeting.

The Treasurer then presented his report stating that all funds were very well accounted for with the exception of some Acheson fund principal. The Finance Committee was then empowered to reinvest these principal sums that are now drawing 2 per cent interest in the East River Savings Bank.

Dr. Warner proposed a list of future meeting places beyond 1956 as follows:

1957: Buffalo and Washington
1958: New York and either Toronto or Ottawa
1959: Philadelphia and Columbus
1960: Chicago and a location such as Asheville, Chapel Hill, or the Pacific Northwest
1961: Detroit and Houston.

The Secretary requested some flexibility in this program to be left to his discretion. This was allowed.

The sub-committee on the Revision of the Constitution and Bylaws has prepared a revised Constitution. This revised Constitution was distributed to the Board and the Secretary was requested to distribute, by mail, additional copies accompanied with his comments. All members of the Board were then directed to study the new Constitution and send their comments to Dr. Warner, with copies of these comments to the Secretary.

Walter Prine, Chairman of our Sustaining Membership Committee, reported on activities, and requested that the following be appointed to his committee, subject to acceptance by the appointees: Robert Woofter, E. A. Schumacher, and J. A. Orsino; at the same time, he announced the resignation, at his own request, of J. C. Schumacher.

In connection with advantages to be offered to sustaining member companies, it was agreed that in the future each company, regardless of the number of memberships held by that particular company, would receive one bound volume of the JOURNAL, in addition to the monthly subscription. Stocks on hand are not sufficient to allow this policy to go into effect during the present year (1953). However, it was agreed that if the sustaining member companies desire this service, the National Office will arrange for the binding of the copies of the JOURNAL now being distributed to them for the current year. In the future, sufficient copies will be reserved to make this service possible.

The revitalization of the Publicity Committee was discussed at great length, as a result of communications between Mr. Fred Peters and President McKay, discussion to be continued.

Dr. Burns reported on the activities of the Publication Committee, pointing out that the backlog of technical papers is increasing, and that the budget for publication must be increased in order to cut down the time between arrival of manuscripts and final publication.

Dr. Burns made a motion of greetings and good wishes from the Society and the Board of Directors to Dr. and Mrs. Colon G. Fink, these greetings to be delivered by their son, Fred Fink.

The meeting adjourned at 4:10 P.M.

HENRY B. LINFORD, *Secretary*

TREASURER'S REPORT—JUNE, 1953

Acheson Fund

Total Acheson Fund Balance 5/31/53		$1,812.24
Guaranty Trust Company, *Custodian*		
Income Balance 5/31/53 (includes Prin. Fds. of $97.43)		1,075.74
Credit:		
Dividends: National Lead Co. 7% Pfd. Stk.	$35.00	
International Harvester 7% Pfd. Stk.	43.75	78.75
Income Balance 6/30/53		1,154.49
East River Savings Bank Principal Funds Balance 6/30/53		736.50
Total Acheson Fund Balance 6/30/53		1,890.99

Edward Weston Fund

The Hanover Bank, *Trustees*		
Principal Account Balance 6/30/53	$57.31	
Checking Account Balance 6/30/53		$26.28
Income Account Balance 6/30/53		204.00
Total Weston Fund Balance for Fellowship 6/30/53		230.28

Consolidated Fellowship Fund

National City Bank Balance 5/31/53		$27.44
Debit: National City Bank charges, postage, etc.	$5.00 0.49	5.49
National City Bank Balance 6/30/53		21.95

Corrosion Handbook Fund

Total Corrosion Handbook Fund 5/31/53	$14,539.42
Corn Exchange Bank	
USA Savings Bonds Ser. F (earmarked in safe deposit box)	10,471.37
New York Savings Bank Balance 6/30/53	4,068.05
Total Corrosion Handbook Fund 6/30/53	14,539.42

Richards Memorial Fund

Central Savings Bank Balance 6/30/53	$731.00

Columbus Convention Fund

Corn Exchange Bank	
USA Savings Bonds Ser. F (earmarked in safe deposit box)	$400.00

LETTER TO THE EDITOR

NEPHELOMETER. Bulletin explains in simple terms a somewhat new method of measuring haze or turbidity in liquids. Also shows why this nephelometer can eliminate 5 out of 7 steps necessary to haze or turbidity measurements; only preparation and precipitation of the sample is needed. Coleman Instruments, Inc. P-151

CONTINUOUS PROCESSING UNIT. Twelve-page, two-color bulletin on the "Turba Film" evaporator describes the use, dimensions, and operation. The new stainless steel processing unit concentrates, distills, deodorizes, degasses, deaerates, heats and cools or otherwise processes liquids, gases, and slurries in a few seconds by continuous operation. Rodney Hunt Machine Co. P-152

CHEMICALS. Folder describes Alcoa's many chemical products, including activated, calcined, low-soda, tabular, hydrated, and catalyst aluminas; fluoride; cryolite; and gallium. Also, 8-page booklet telling of the uses of aluminum in such industries as plastics, soaps, cosmetics, drug products, sulfur, petroleum, and chemicals. Tables given covering materials handled safely with aluminum, composition and properties of aluminum alloys, etc. Aluminum Company of America. P-153

PRESSURE TRANSDUCERS. Data sheet on new series of Barium Titanate Pressure Transducers, Models BC-10, BC-30, and BC-50, generally useful as transient pressure pickups in liquid and gaseous systems. Gauges produce large voltage response (up to 0.6 volts/psi) flat over wide frequency ranges (3 c/s—75 kc/s, 1 c/s—40 kc/s, and 0.5 c/s—30 kc/s, respectively). Atlantic Research Corp. P-154

PROJECTION BALANCE. Manual explains new Universal balance. The instrument, claimed to be a completely new concept in balances, is fully illustrated; diagrams and photographs describe the unusual features, including beam and projection systems, weight operation, compensating stirrups. Voland & Sons, Inc. P-155

ELECTROPLATED GOLD. Technical data sheet on electroplated gold shows the way to scientific control of the process, and offers the scientist the most complete compilation of information on gold that has been assembled to date; also some data believed unavailable heretofore. Technic, Inc. P-156

NEW PRODUCTS

MULTI-SEQUENCY PROCESS CONTROL. Versatile new electronic predetermined counter has been designed for use wherever precise, multiple-sequence control of manufacturing processes is desired. Increased production and reduced spoilage achieved as it is possible to govern operation of production machinery in terms of lineal measurement, shaft revolutions, quantity, volume, or weight at operation speeds as high as 60,000 per min. Potter Instrument Co., Inc. N-24

PORTABLE INDICATING INSTRUMENTS. Two series of improved portable electric instruments designed for maximum convenience and readability have been announced. The new instruments are available to indicate volts, watts, amps, and milliamps. DP-11 is for general testing when a rugged, easily-read indicating instrument is needed; DP-12 is a high-precision testing instrument for laboratory, field, and production use. General Electric Co. N-25

AUTOMATIC TRANSISTOR CURVE TRACER. New automatic universal transistor curve tracer is announced. Recommended for designing transistor circuits; comparing, matching and selecting; detecting anomalies; studying the effects of temperatures, age, normal usage, overloading, and detecting failures and their causes. The curve tracer tests NPN, PNP, Junction and Point Contact Transistors, and features flexibility of design to accommodate new types as produced. Magnetic Amplifiers Inc. N-26

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To receive further information on any New Product or Literature from Industry listed above, send inquiry, with key number, to JOURNAL of The Electrochemical Society, 216 West 102nd Street, New York 25, N. Y.

Please print your name and address plainly.

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Editorial

Promotion of Industrial-Educational Understanding

THE founding of the Industrial Council by Rensselaer Polytechnic Institute as a medium of communication and understanding between industry and education should prove to be a significant contribution to the American free enterprise system. The activity of the Council consists in the presentation of a two- or three-day program arranged by the Institute, held on its campus and devoted to the portrayal of American industry, its characteristics, its problems, and its contributions to modern life. At each session, an important industrial group acts as host and invites as its guests the teachers of social studies from secondary schools and colleges in all parts of the country. The first session was sponsored by the oil industry; the second, held last May, by the chemical industry. This month the electrical industry will be host at the third convocation.

The program of the chemical meeting consisted of addresses by several leaders of the industry, followed by 18 panel conferences that provided opportunities for detailed discussions stimulated by the questions from many of the 800 teacher-guests. It became apparent in the course of the discussions that these teachers, who have so much to do in conditioning the minds and shaping the thinking and attitudes of the nation's young people, had very little knowledge of the character and accomplishments of American industry. The viewpoint of many of them reflected their exposure to labor-union and left-wing propaganda; others reported that they sought information concerning industry, but were forbidden by timid or "psychoceramic"[1] school authorities to make use of the limited amount of material received from industrial sources. However, in some more enlightened areas of the country, teachers may choose their material from even such sources as the National Association of Manufacturers. It was gratifying to note that the teacher-guests attending the recent meeting readily accepted the excellent "Facts Book of the Chemical Industry," just issued by the Manufacturing Chemists Association.[2] This is a 108-page booklet of up-to-date and fascinating information concerning the chemical industry.

It is clear that industrialists as well as teachers profit from their attendance at meetings of the Industrial Council. Industries supporting this project are to be complimented for their contribution to public education and ultimately the general welfare.

Trygve Lie, who addressed the first session of the Council, stressed the broad significance of its work in the following words:

"Wider understanding and knowledge of the great industries that play so central a role in the life of our times is certainly important both for individual nations and for the world. To bring together, as you are doing, the leaders of one great industry after another, starting with the oil industry—with writers, teachers, and students specializing in history, economics, and sociology—seems to me a practical and sensible contribution to this end. As Secretary General of the United Nations, I have a special interest in all efforts to promote wider understanding of the world we live in, of the many forces at work in the world, and how these forces can affect the progress toward the main goals of the United Nations—a more secure peace, wider freedom, more equal opportunity, and higher standards of living for people in all parts of the world."

—RMB

[1] Current American vernacular for "crack-pot."

[2] Procurable from Manufacturing Chemists Association, Woodward Building, 15th and H Streets, Washington 5, D.C. Price $1.00.

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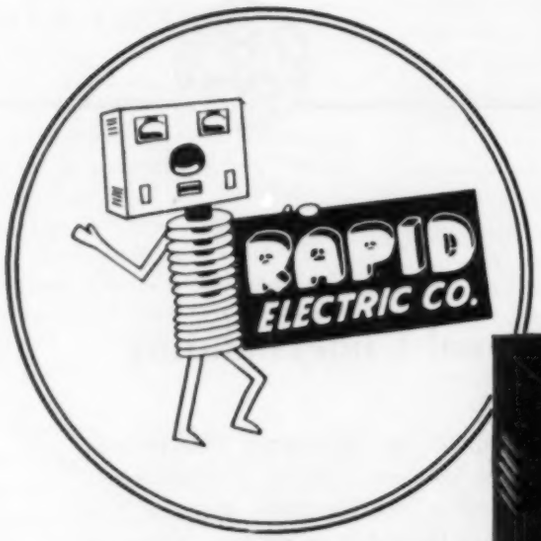

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Current Affairs

Candidates for National Society Offices (1954–55)

Marvin J. Udy

Presidential Candidate

Marvin J. Udy, Consultant in metallurgical and electrochemical engineering, Niagara Falls, New York, is a native of Utah and a graduate of the University of Utah, class of 1915. He received the M. S. degree from the same school in 1916 and, in the two years following, was assistant research chemist at the

MARVIN J. UDY

U. S. Mining and Smelting Corporation in Utah.

Mr. Udy then came east to join the Hooker Electrochemical Company and later became chief chemist and research engineer of the Haynes Stellite Company. While there he developed a process for cadmium plating, the patents for which formed the basis of the Udylite Process Company, now of Detroit. Other connections of Mr. Udy include the Electrometallurgical Company of Niagara Falls, where he was employed for a period of eleven years, and the Swann Chemical Company of Alabama which he joined in 1931. Following this he became research and development engineer for Oldbury Electrochemical Company.

In 1937 Mr. Udy developed "Chrom-X" for the Chromium Mining and Smelting Company. "Chrom-X" is an exothermic ferrochromium produced from low-grade chromite ores and has found a wide use in the steel industry. He at present enjoys a wide consulting practice in the metallurgical field and electric furnace smelting.

Mr. Udy was the recipient of the Schoellkoff Medal in 1948. He has been a member of The Electrochemical Society since 1919, serving for three years as Manager; he has also been vice-chairman and then chairman of the Niagara Falls Section. He was General Chairman for the 1950 convention at Buffalo.

Norman Hackerman

Vice-Presidential Candidate

Norman Hackerman was born in Baltimore, Maryland, in 1912. He received all of his college training, including graduate work, at Johns Hopkins University, receiving the Ph.D. degree in physical chemistry in 1935. Thereafter he was appointed assistant professor of chemistry at Loyola College in Baltimore, later serving as research chemist for the Colloid Corporation in that city. In 1941 he was appointed assistant professor of chemistry at Virginia Polytechnic Institute, which he left in 1944 to work on the Manhattan Project.

Dr. Hackerman joined the University of Texas staff in 1945; he is currently professor of chemistry, chairman of the department, and director of the Corrosion Research Laboratory. His research interests deal principally with the chemistry and physics of surfaces, especially as these phenomena apply to metal corrosion. Recently he and his students have published numerous articles on adsorption on metal surfaces and its influence on electrochemical properties and reactivity, and on the passivity of metals.

As a member of The Electrochemical Society, Dr. Hackerman served as chairman of the Corrosion Division in 1951, and has been Technical Editor of the JOURNAL since 1950. He belongs to the American Association for the Advancement of Science, and was the 1950 Chairman of the Gordon Corrosion Research Conference. He also holds membership in Phi Lambda Upsilon,

NORMAN HACKERMAN

Sigma Xi, The Faraday Society, the American Chemical Society, and the National Association of Corrosion Engineers, serving on the Board of Directors for the latter.

Frederick A. Lowenheim

Vice-Presidential Candidate

Frederick A. Lowenheim was born in 1909 in New Rochelle, New York. After the conventional schooling there, he attended Columbia University, where he received his B.A. degree in 1930 and the Ph.D. degree in chemistry in 1934. For his thesis he worked in the field of transference numbers in the nonaqueous solvent sulfuric acid, as a student of Professor L. P. Hammett.

After a short time in another position, Dr. Lowenheim came to Metal and Thermit Corporation in 1936; he is now supervisor of Electrochemical Research at the company's Woodbridge, New Jersey, Laboratories. His work has been of varied nature, including different phases of inorganic technology. In recent years, he has tended to concentrate in the electrochemical field with particular emphasis on electrodeposition, especially of tin and its alloys. He has contributed papers on this and related subjects to the TRANSACTIONS OF THE ELECTROCHEMICAL SOCIETY as well as to many other publications, and he holds several patents in this field. During the war, he was particularly active in the strip steel electrotinning program. For the past three years, he has conducted a series of lectures at Stevens Institute of Technology on advanced inorganic chemistry.

FREDERICK A. LOWENHEIM

Dr. Lowenheim's activities in The Electrochemical Society have included the chairmanship of the Electrodeposition Division and of the New York Metropolitan Section; he has more recently served the New York Section as Secretary-Treasurer. He is particularly interested in the affairs of the local sections, being at present Chairman of the Local Section Advisory Committee; and he has served as Finance Chairman for three national conventions, two in New York and one in Wrightsville Beach. He is a member of the Editorial Advisory Board and has contributed chapters to the forthcoming Electrochemical Society Monograph on "Modern Electroplating."

JOHN R. MUSGRAVE

John R. Musgrave

Vice-Presidential Candidate

John R. Musgrave, Chief Physicist in the Eagle-Picher Research Laboratories at Joplin, Missouri, was born at Reading, Pennsylvania, in 1906. He received his degree in chemical engineering at Lafayette College in 1927. Following a period of industrial research, he entered the graduate school of the University of Toronto. There he received the Ph.D. degree, majoring in physical chemistry, in 1933. Shortly after the completion of his graduate work, he became affiliated with the Eagle-Picher Research Laboratories, where he is, at present, in charge of the Physical-Chemical Section of the Laboratories.

Dr. Musgrave's research activities cover work on thermal insulation, storage batteries, paint, corrosion, instrumentation, diatomaceous earth, and rare metals. He has been active in the development of high-purity germanium for semiconductor work, as well as gallium. He holds several patents and is the author or co-author of technical papers on storage battery technology, particle-size determination (in the subsieve range), germanium, and gallium.

Dr. Musgrave joined The Electrochemical Society in 1941 and has been particularly active in the Battery and Electronics Divisions. He has been secretary-treasurer and chairman of the Electronics Division and has participated in the development of the rare metals and semiconductor symposia. He is presently a member of the Acheson Award Committee as well as several other Society committees. He is also a member of a number of other scientific organizations.

Corrosion Division Essay Winners

The first prize of one hundred dollars for the best essay on the topic "Contributions of Electrochemistry to Science" is to be shared equally by Ahmad Geneidy of West Virginia University and Alvin P. Ginsberg of New York University. Each will receive also a one-year membership in the Society. The second prize of fifty dollars has been awarded to Robert S. Johnson of Monmouth College, Monmouth, Illinois. He, too, will receive a one-year membership in the Society. The following contestants were given honorable mention and a year's subscription to the JOURNAL: Eugene Ashby (address not furnished); Robert Auerbach, New York University; Herbert L. Bullard, John B. Pierson, Richard Prouty, and Elizabeth Holmes, all of Alabama Polytechnic Institute; Miss Jariwala L. Jayshri of St. Xavier's College, India; and Dorothy Bump (now Mrs. Clinton Ryno), Roger Ray, Elwood Richard, and Warren Trask all of Monmouth College.

These young people are all to be congratulated upon the well-written and thoughtful papers which they submitted. It is to be hoped that what they learned about electrochemistry has stimulated an interest in this subject and in science generally. The Society is gratified at the encouragement to student interest in the prize essay contest shown by the institutions with which these contestants were connected. The Corrosion Division, in sponsoring a prize essay contest, is making an important contribution toward publicizing in the colleges and universities the nature and accomplishments of electrochemistry and the existence of this Society.

Electronics—Semiconductor Symposium Planned for Chicago

The Semiconductor group of the Electronics Division is planning a symposium for the Chicago Meeting, to be held May 2–6, 1954. This symposium will feature intermetallic compound semiconductors such as the antimonides, arsenides, and phosphides. In addition, sessions are planned for germanium, silicon, and other semiconductors.

Papers will be considered on new and old semiconductors, their electrical, chemical, and metallurgical properties, and preparation and fabrication meth-

ds; closely associated geometrical and electrical requirements on imperfections in semiconductors, and mechanical and chemical combinations of semiconductors with other materials to achieve a particular solid-state electrical device; techniques of producing conducting films and compositions, and devices made from them, as well as analytical studies of effects of environmental conditions on surface and bulk properties and structure of semiconductors and semiconductor devices; and closely related subjects.

Five copies of manuscripts or abstracts (not to exceed 75 words in length) must be received at Society headquarters, 216 West 102nd Street, New York 25, N. Y., not later than January 15, 1954. The title of the paper should also be sent to the Chairman of the symposium, A. E. Middleton, Battelle Memorial Institute, Columbus 1, Ohio.

A second "extended abstract" of about 1000 words must be submitted not later than February 1, 1954 to A. E. Middleton. This extended abstract is "*printed, but not published*" in a booklet which will be available, at cost, before and during the meeting. Abstracts of papers (luminescence, screen applications, etc.) presented in other groups of the Electronics Division will also appear in this booklet.

Bell Labs Develops Important New Diode

A new electronic device which may result in revolutionary advances in telephone switching systems and in many kinds of computers has been created by Bell Telephone Laboratories, research and development organization of the Bell System.

Described as a silicon alloy junction diode, it serves as the electronic equivalent of a tiny one-way switch. Thus it acts as a rectifier. Also, it is capable of operating thousands of times faster than its mechanical counterparts. Switches of this type can perform as deft fingers operating the telephone dial system—or enabling mechanical computers to make complex calculations in a fraction of a second.

A diode may be compared to a pipe with a check valve which allows water to flow in one direction but blocks it from flowing in the opposite direction. The back leakage, which is never completely prevented, is smaller than in any previous diode—and the leakage currents of vacuum-tube diodes may be a thousand times greater. The new diode also contrasts sharply with the two-element vacuum tube in that it requires no filament or vacuum. It has an encased element no larger than a match head, and is an accomplishment growing out of transistor research and development. Its lifespan should be almost unlimited.

New Dow Research Center in Honor of W. R. Veazey

Dedication of a new $2,600,000 research center at The Dow Chemical Company's Texas Division in honor of Dr. William Reed Veazey, recently retired Dow director and research consultant, will take place in October.

In its 69,000 ft² of space, the research center will house the Texas Division's organic, chemical engineering, and electrochemical research, as well as the analytical laboratory, and will also include research administrative offices, a patent office, and a library.

Dr. Veazey began his association with Dow in 1915, when he undertook special research work in magnesium. At the time he was an assistant professor at the Case School of Applied Science, now Case Institute of Technology, in Cleveland. In 1916 he headed a developmental group which succeeded in producing the first pound of magnesium metal ever made in the States.

Dr. Veazey remained on the Case staff until 1936, meanwhile continuing special Dow work; that year he resigned

from Case to join Dow permanently in Midland. He served successively as coordinator of research, patent and product development, head of the Executive Research Committee, and as a research consultant.

He is a past president of The Electrochemical Society and has been a member of the American Chemical Society and the American Institute of Chemical Engineers for many years. At the time

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of his retirement, Dr. Veazey was a director and vice-president of Dowell Incorporated, a Dow subsidiary, and a director of Dow Corning Corporation, an associated company.

New Development by Lindberg Engineering

Carbon and sulphur contents of ferrous alloys can be determined in a single operation with procedure introduced by the Laboratory Division of Lindberg Engineering Company, Chicago, Illinois. The procedure uses the Lindberg High Frequency Combustion Unit to heat specimens by inductive heating to temperatures above 3000°F. Heat is generated in the sample only.

Lithium Corp. Liquidates Subsidiary

K. M. Leute, president of Lithium Corporation of America, Inc., Minneapolis, Minn., has announced that, effective July 1, 1953, the company has liquidated its wholly owned subsidiary, Metalloy Corporation. Metalloy previously has operated as the chemical and sales division of the parent company. Hereafter, all business will be conducted under the name of Lithium Corporation of America, Inc.

PERSONALS

JOHN J. STOBIE, Apex Smelting Company, Chicago, Ill., has been appointed sales engineer of the company's West Coast plant and will be located at Apex Smelting Company, Long Beach, Calif.

WALTER BECK has joined the Department of Materials Engineering, Syracuse University, East Syracuse, New York. Dr. Beck formerly resided in New York City.

ROBERT L. CRONE is now associated with the Hughes Aircraft Company of Culver City, California, as a member of the technical staff. Mr. Crone was formerly with Radio Corporation of America, Victor Division.

RALPH M. HUNTER, prominent in the nation's electrochemical industry, has been advanced to the position of staff coordinator of all electrochemical activities for the Dow Chemical Company, according to a recent announcement. In his new capacity Dr. Hunter will coordinate electrochemical operations on a company-wide basis and facilitate the exchange of research and development information. He will, however, retain active charge of the Midland Electrochemical Laboratory.

CLIFFORD A. HAMPEL, chemical engineering consultant, of Homewood, Illinois, has been elected president of the Chicago Technical Council, a federation of scientific, engineering, and technological societies. Mr. Hampel is editor-in-chief of the *Encyclopedia of Chemical Reactions*, and is currently engaged in editing a forthcoming *Handbook of Rare Metals*.

RUSSELL B. SNYDER has recently been named second vice-president of The Rauland Corporation, Chicago, Illinois. He was formerly Chief Chemist of the company.

D. GARDNER FOULKE, formerly chief chemist at the Hanson-Van Winkle-Munning Company, Matawan, New Jersey, has been appointed manager of electrochemical development of the company.

I. MELVILLE STEIN, formerly executive vice-president of Leeds and Northrup Company, Philadelphia, Pa., has been elected president of the company. Mr. Stein joined Leeds and Northrup in 1919. During World War I, he had been personal assistant to Thomas A. Edison when the inventor was chairman of the Naval Advisory Board and was cited for his work throughout World War II. In 1928, he was appointed director of research at Leeds and Northrup, in 1944 vice-president, and in 1951 executive vice-president.

ROBERT M. PARKE has been promoted to manager of the materials and processes section of the Metallurgy Research Department, General Electric Research Laboratory, Schenectady, New York.

EDWARD B. SANIGAR

Edward B. Sanigar of the Naval Radiological Defense Laboratory, San Francisco, died on July 28, of a heart ailment.

Dr. Sanigar joined The Electrochemical Society in 1929 and was one of its active workers. Among his activities in the Society were service on the Publication Committee, Vice-Chairman of the San Francisco Section, and Chairman of the same Section.

Dr. Sanigar received the B.Sc. and M.Sc. degrees from Sheffield University and he studied at Columbia University on the Edward Weston Fellowship. He was investigator for the British Government Electrodeposition Committee and the British Non-Ferrous Metals Research Association from 1926–29. For the following two years he was research chemist at Leeds and Northrup Company in Philadelphia. From 1933–35 he served as research chemist and investigator in cancer research at Pennsylvania Medical School. He joined the staff of the Biochemical Research Foundation, Franklin Institute, as a research physical chemist in 1935, becoming head of the physical chemistry department in 1941. In 1947 Dr. Sanigar became associated with the radiation laboratory of the San Francisco Naval Shipyard as a physical chemist and the following year was appointed Assistant Scientific Director of the Naval Radiological Defense Laboratory, continuing in this capacity until the time of his death.

LETTER TO THE EDITOR

Oxidation of Metals at High Temperatures

Dear Sir:

The recently published paper with this title[1] included a suggested mechanism for oxidation of Ti and Zr that is probably not valid. It was stated that the large negative entropy of activation ΔS^* for the parabolic oxidation rates of these metals might be due to diffusion via anionic vacancies. It should have been evident, however, that such anionic diffusion cannot yield a large negative ΔS^*, since the concentration of oxide-ion vacancies would be highest at the metal-to-oxide interface and close to zero at the oxide-oxygen interface. Thus, the formation of anion vacancies in films of ZrO_2 and TiO_2 would not be associated with the loss of freedom of gaseous oxygen that can lead to large negative ΔS^*. On the other hand, inward migration of interstitial oxygen or of oxygen along grain boundaries would lead to negative ΔS^* values. The higher temperature oxidation of Zr (500°–900°C) with $\Delta H^* = 32.0$ kcal and $\Delta S^* = -7.1$ cal deg^{-1} may, however, represent anionic vacancy migration.

In view of the evidence available at present, it now seems most likely that the oxidations of Zn, Al, Ti, and Zr, at temperatures below 500°C, all proceed by migration of interstitial

1. W. J. MOORE, *J. Electrochem. Soc.*, 100, 302 (1953).

cations. The large negative ΔS^* then arises because the cations are formed from interstitial atoms by some reaction such as the following:

$$Zn_i + O_2(g) \rightarrow Zn_i^+ + O_2^- \text{ (ads.)}$$

This reaction would lead to the loss of the entropy of oxygen (S_1), the gain in entropy by formation of a tightly adsorbed O_2^-(S_2), and some gain in entropy due to replacement of Zn_i by Zn_i^+(S_3). Thus, with reasonable estimates of the entropies involved,

$$-\Delta S = S_1 - S_2 - S_3$$
$$= 50 - 10 - 10 = +30 \text{ cal deg}^{-1}.$$

The experimental ΔS^* values range from -23 to -29, so that a reaction of the type proposed can readily account for the observations. It has already been shown how this mechanism serves to explain the experimental values of the activation energies.[2]

The electric field caused by the surface oxide ions may also affect the migration rates of the interstitial cations, as has been emphasized by Cabrera and Mott[3] and by Engell and Hauffe.[4] The latter authors are probably correct in their analysis of the pressure dependence of zinc oxidation[5] as evidence for the electric field effect.

It should now be evident that, for both n- and p-type oxides, large negative ΔS^* in parabolic rate constants can be explained in terms of the loss of freedom of the attacking gas in the step leading to formation of the migrating defects.

W. J. Moore
Indiana University
Bloomington, Indiana

2. W. J. Moore, *J. Chem. Phys.* **20**, 764 (1952).
3. N. Cabrera and N. F. Mott, *Rep. Prog. Phys.*, **12**, 163 (1949).
4. H. J. Engell and K. Hauffe, *Metall.* **6**, 285 (1952).
5. W. J. Moore and J. K. Lee, *Trans. Faraday Soc.*, **47**, 501 (1951).

BOOK REVIEWS

Ferroelectricity by E. T. Jaynes. Published by Princeton University Press, Princeton, N. J., 1953. 146 pages, $2.00.

This short book does not attempt to cover the entire subject. It is primarily a rather well done critical review of the theories of ferroelectricity, aimed at guiding the research worker through a literature extraordinarily full of errors, misunderstandings, and conflicting points of view. Secondarily, the author gives in detail a number of his own new theoretical results. The best thing about the book is that one comes away with the correct impression that most of the questions are still open. On the other hand there is no attempt to give the reader general background in the subject, and only a sketchy discussion of the experimental work.

This book will be valuable to the research worker in the field of ferroelectricity, but of little use to the more general reader.

P. W. Anderson

Quantitative Analysis by Harvey Diehl and G. Frederick Smith, 539 pages. John Wiley & Sons, Inc., New York, and Chapman & Hall, Limited, London, 1952, $5.

This is an excellent elementary textbook on quantitative analysis, designed for use in second-year college work. Its 19 chapters cover all of the customary theory and practice of chemical analysis in a well-organized, well-illustrated, and clearly presented man-

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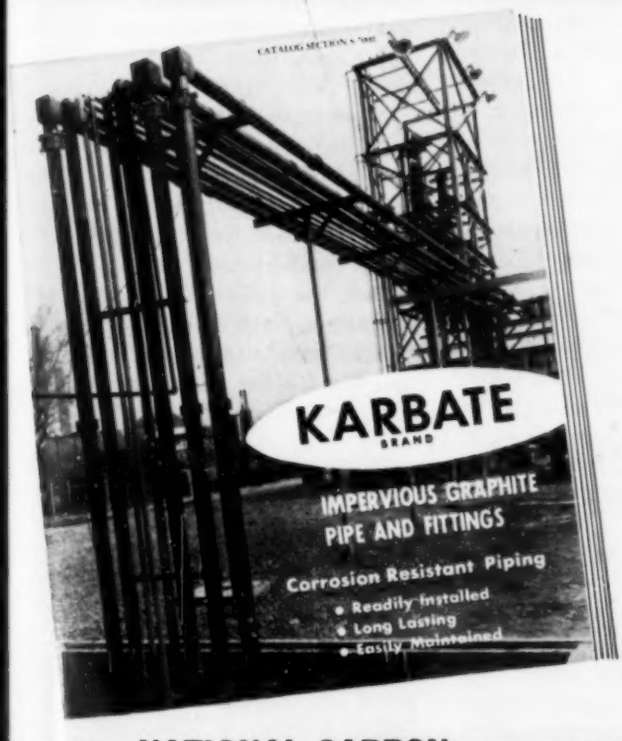

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ner. The book should be most welcome to teachers, for the subject has been so skillfully handled in most instances that very little amplification on the part of the instructor is necessary. Students will also find it attractive because the style is such as to make the context easily understood.

The book has been written by two of this country's most eminent analytical chemists. Since their efforts have been largely directed toward the development of useful methods of chemical analysis, it is natural that the new textbook reflects the approach of the practicing analytical chemist. Detailed instruction in the important manipulations of analytical chemistry has been stressed in place of the usual, somewhat excessive, emphasis on theory. This is not to imply that theory has been ignored. In fact, the book places about equal emphasis on theory and practice.

Because of the enthusiasm for analytical chemistry reflected in the writing and because every attempt has been made to use up-to-date knowledge and examples, the textbook should stimulate interest in analytical chemistry as a career.

C. L. Luke

Elektrolytisches Härten (Electrolytic Hardening) by I. S. Jasnogorodski. Translated from the Russian (1949) by Fr. Krantz. Published by Verlag Technik GmbH., Berlin NW7, 1951. 119 pages, approximately $4.35, cloth bound.

The subtitle of this book is "The Heating of Metals and Alloys in Electrolytes." There is a six-page editorial preface explaining the importance of the new method compared to high-frequency induction heating, and mentioning that Jasnogorodski received the Stalin prize in 1947 for the discovery.

Briefly, Jasnogorodski's process consists in treating the surface to be heated as cathode in 5 to 10 per cent sodium carbonate solution at 50° to 70°C and about 200 volts or more of direct current, giving a current density of about 30 amp/in.^{2} Under these conditions, the surface is heated to a very high temperature in from 5 to 10 seconds, and may even be melted. A peculiar light is observed at the cathode, and the author presumes that the heat effect is due to the formation and recombination of hydrogen atoms.

The first chapter describes the work done to investigate the effect of different variables on the process, and the results with a number of different electrolytes. The second chapter describes the process decided upon for commercial work, and some of the equipment used and results obtained. The third and fourth chapters relate largely to a number of automatic and special purpose machines developed by the author for treating various types of parts, welding, sintering, hot forging, and so on.

On the face of it, the book appears to describe a remarkable new process which may prove to be of widespread interest. The principal advantages claimed are high heating velocity, control of area and depth of hardening, avoidance of oxidation, and adaptability to use in automatic machines.

The book seems well written and well illustrated, with 79 figures including line drawings, photographs, and curves. The new development is described entirely without benefit of bibliography, and one wonders if there is no previous similar work or prior art. The author indicates that his investigations began in 1937.

G. Dubpernell

LITERATURE FROM INDUSTRY

Colloidal Graphite. New six-page, two-color bulletin on "Colloidal Graphite for Surface Coatings and Impregnation" is now available. Electric furnace graphite of high purity, when rendered colloidal and dispersed in a suitable carrier, finds new uses as a dry-film lubricant—surface coating for many mechanical devices—and as impregnating medium for such materials as porous minerals, cloth, asbestos, and paper. Acheson Colloids Co. P-157

Pump Application Guide. A new type of reference chart on small pump applications lists the various types of pumps, services for which each is built, and the performance and special features of each. Tuthill Pump Co. P-158

Dimensional Data Sheets. A new series of dimensional data sheets on a line of valves for fluid control has just been released, giving complete valve dimensions. They should prove extremely valuable in planning or designing new equipment in instrumentation or industrial fields. Hoke, Inc. P-159

Differential Voltage Indicator. Bulletin describes a new indicator, designed to measure differential voltage, as well as amperage, speed, pressure, and other quantities which can be converted to voltage. The device features a self-balancing circuit which possesses a high degree of stability and freedom from drift. Can be used with standard accessories, such as a recorder, indicating instrument, or alarm relay. General Electric Co. P-160

Power Supplies. Twenty-page catalogue and new condensed brochure have just been released describing Voltage Regulated Power Supplies. Of interest to all users of electrical and electronic equipment. Kepco Laboratories, Inc. P-161

Gages and Valves. New folder describes line of liquid level gages and valves, water columns, gage illuminators, etc. Features include safety, readability, and pressure. Jerguson Gage & Valve Co. P-162

Yardney Silvercels. Brochure and technical data sheets announce several new high-capacity models of silver-zinc alkaline cells which feature unusually high discharge currents and are rated at 100 amp-hr. Up to six times lighter and five times smaller than ordinary storage cells of comparable capacity; spillproof and highly efficient; free from corrosive fumes, vapors, spray, and gassing; high discharge rates; and flat output voltage characteristics. Yardney Electric Corp. P-163

New Clad Metals. New pamphlet describes nine new developments in the field of clad metals. Detailed information given on the cupralum anode, the ferrolum anode, ferrolum lead clad steel immersion heater, the Knapp lead-plate heater, the Universal pipe supporter, the automatic lead cladding machine, Knapp Raysist compounds, lead-lube, and the Guidler. Knapp Mills Inc. P-164

Plastic Coating and Compound. Two new leaflets on plastic coating, and cleaning and phosphate coating have been published. The former describes the use and application of a new vinyl-type coating for paint spray booths. The coating is easily peeled off, taking with it all paint overspray, to give quick, low cost maintenance. The latter leaflet describes a compound use for cleaning and imparting a fine-grained phosphate coating to steel parts to provide a good paint bond. Detrex Corp. P-165

NEW PRODUCTS

HIGH PRESSURE FILTERS. High pressure liquid and gas filters have been added to the line. Standard units are available for operating pressures up to 1000 psi; filters for even higher pressures also available. Construction is all welded steel. Cuno Engineering Corp. N-28

METAL CLEANER. New metal cleaner, Detrex 63, specially formulated for use in the vitreous enameling industry, has been developed. Described as a medium-high alkaline compound containing very high wetting and penetrating properties. Exceptional ability is claimed for emulsifying large quantities of mineral oils and greases and for keeping them in a state of suspension. Detrex Corp. N-29

NEW "B" TYPE BATTERY. Smallest alkaline-type "B" battery designed for use in current personal portable radios has been announced. This midget 45-volt "B" battery (VSO86) weighs approximately 3 oz. and is $3^{9}/_{16}$ in. long, $1^{1}/_{16}$ in. wide, and $^{11}/_{16}$ in. deep. The small size and excellent performance stem principally from its alkaline-cell construction which permits more efficient utilization of the battery cell's active materials. RCA Victor Division, Radio Corporation of America. N-30

AUTOMATIC RECLOSING RELAY. An automatic reclosing relay (RC) with a built-in instantaneous trip lockout feature is now available. Applicable to all types of circuit breaker control schemes. Adjustable reclosing time sequences of 60, 90, 180, or 360 seconds are provided by a 600-rpm synchronous motor with a gear train of adjustable ratio. May also be obtained with an adjustable integrating lockout device which limits successive circuit breaker reclosures to a safe value. Westinghouse Electric Corp. N-31

ELECTRO POLARIZER AND PORTABLE GALVANOMETER. Chemical analysis of plating solutions now can be analyzed with a great degree of accuracy and speed by means of an electro polarizer and a portable galvanometer. The new Patwin electro polarizer utilizes the polarographic method of analysis and can be used to analyze most plating solutions, including copper cyanide, zinc cyanide, cadmium, brass, and nickel. The G-E galvanometer measures the low values of current or voltage. Its high sensitivity is made possible by alnico magnets, which provide a field of more than twice the strength obtainable with chrome-steel magnets. General Electric Co. N-32

STABILIZED CRYSTAL. A new stabilized crystal, the JK G-12, specially designed to handle applications in the "difficult" 500 to 1500-kc range, has just been introduced. The unit provides ultra-stable frequency control for applications such as frequency standards, timing and counting circuits, broadcast equipment, and frequency monitors. Use of the evacuated glass envelope assures freedom from contamination, and greater shock resistance. James Knights Co. N-33

To receive further information on any New Product or Literature from Industry listed above, send inquiry, with key number, to JOURNAL of The Electrochemical Society, 216 West 102nd Street, New York 25, N. Y.

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RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

May 5, 1953

Kendall, T. L., and Gentry, D. P., 2,637,209, Electrolyte Level Indicator

Udy, M. J., 2,637,648, Production of Ferrosilicon

McKay, R. J., 2,637,686, Process of Producing Drawn Articles

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Myers, R. R., Jr., 2,637,689, Device for Making Curved Electroplate Shells

Coleman, J. J., and Wilke, M. E., 2,637,756, Deferred Action Battery

Wilke, M. E., 2,637,757, Deferred Action Battery

Shannon, J. K., 2,637,758, Storage Battery

Shannon, J. K., 2,637,759, Storage Battery Cell Cover and Construction

Boyer, J. L., and Albert, W. S., 2,637,827, Alkali-Metal Rectifier

Sharkey, A. J., 2,637,830, Treatment of Electric Lamp Envelopes

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Nelson, H. F., 2,637,760, Storage Battery Testing and Filling Apparatus
Kendall, T. L., Bodenhafer, C. B. and Plummer, R. I., 2,637,836, Method for Charging Storage Batteries

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Schoch, E. P., 2,638,443, Method and Apparatus for Glow Discharge Treatment of Gases
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Passal, F., 2,640,021, Composition, Bath, and Process for Chromium Plating
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Palmateer, R. E., 2,640,024, Electrophoretic Borating of Copper Wire
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Hesch, F. H., 2,640,806, Process for Polishing Aluminum
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Herres, S. A., 2,640,860, Apparatus for Melting Titanium to Form Ingots
Kremers, H. C., 2,640,861, Resistance Furnace
Chubb, M. F., 2,640,862, Battery Pigment
Ellis, G. B., 2,640,863, Deferred Action Type Battery
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Wellman, W. C., 2,642,391, Anodic Rod Holder
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Urbach, F., 2,642,538, Thermal Radiography Using Phosphors

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June 23, 1953

Zimmerman, H. M., 2,642,628, Method of Forming a Wet Cathode Portion
Ahrens, G. W., 2,642,654, Electrodeposited Composite Article and Method of Making the Same
Savidge, L. N., and Thomas, R., 2,643,-197, Fluorescent Alkoxy Benzoyl Derivatives of 4,4′ Diamino Stilbene-2,2′ Disulfonic Acid and Detergent Compositions Containing Same
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Brenner, A., Couch, D. E., and Williams, E. K., 2,643,221, Electrodeposition of Phosphorus-Nickel and Phosphorus-Cobalt Alloys

Editorial

Electrochemical Industry of Canada

In this issue of the JOURNAL is the first of three articles concerning the electrochemical and electrometallurgical industries in Canada, and the virile electrical generation network on which they depend.

Electrochemistry and electrometallurgy have already made gigantic strides in Canada. Their continued advance is assured, for the electric industry in Canada is marching ahead year after year.

Last year it generated 69 billion kwhr, next after only the United States and presumably the Soviet Union. In straight terms of energy, on the formula that a kilowatt is equal to the strength of 13 men, and assuming a human work-year of 2,400 hours, that electrical energy gave Canada the equivalent of a working force of 368,000,000 men. Or, because just two-thirds of Canada's electrical power is devoted to industry, say it's equal to only 240,000,000 men.

Fanciful? Yes, but the nation north of the border, about one-tenth the population of the United States, is nevertheless recording some astonishing achievements.

She is sixth among all nations in production of goods. She is third in world trade. She is vital to the United States not only as a continual good neighbor and because of her strategic position, but also as a supplier of things the United States needs and as a market for American goods.

Canada has an immense wealth of natural resources, and one of the greatest of them all is her abundance of water-power which permits relatively inexpensive development. Of the 20 greatest hydroelectric generating stations on this continent, half are in Canada—and more are being built all the time. Recently the rate has approached a million horsepower annually.

This first article, by V. G. Bartram, of Montreal, president of Shawinigan Chemicals Limited and several associated companies, treats of electrochemistry, electrometallurgy, and electric generation throughout the length and breadth of Canada generally. The second article in the series will go into detail of those three phases of the subject in Canada's five eastern provinces—Quebec, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland. The last article will treat of the other five provinces—Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia—and also the Yukon and Northwest Territories.

There is no part of Canada that does not hold some interest for the American industrialist today. The nation of the north is growing steadily, and opening new stores of treasure. She is always willing to share them.

—A. F. G. CADENHEAD

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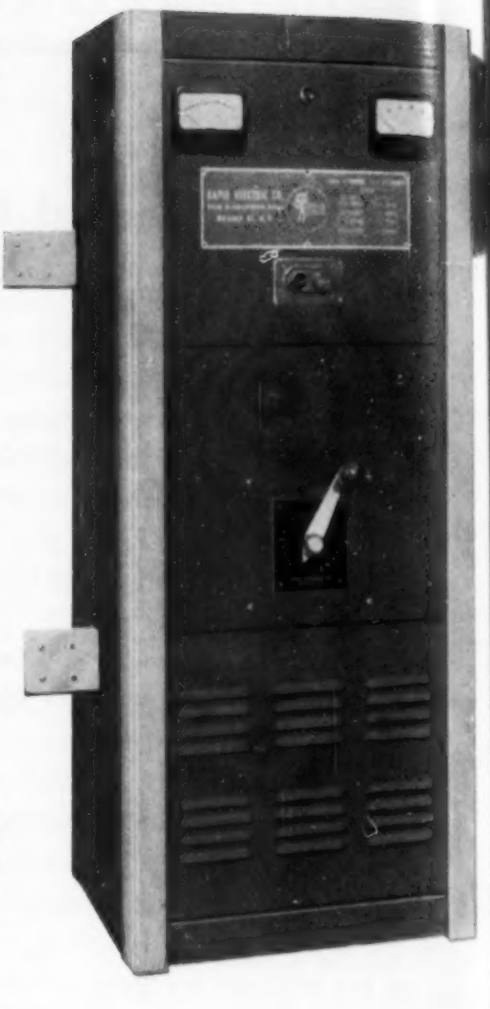

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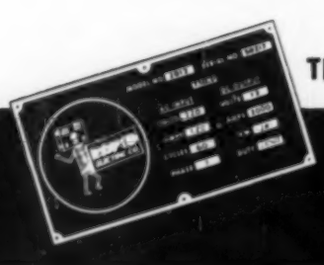

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THE ELECTROCHEMICAL AND ELECTRO-METALLURGICAL INDUSTRIES OF CANADA[1]

V. G. Bartram[2]

The twentieth century belongs to Canada! This slogan, first hopefully phrased in the early 1900's by Sir Wilfrid Laurier, then Canada's Premier, is often heard these days as writers in Canada and in other countries point to the great strides Canada has made in the past fifteen years in her industrialization and in the development of her natural resources. Many excellent articles have appeared in recent months extolling Canada's remarkable progress, and it is not the intention to present here yet another such review. Rather it is the purpose of this series of three articles to examine briefly Canada's electrochemical and electrometallurgical industries, as well as the great hydroelectric developments which have brought them into being, as part of her rapidly growing economy.

General Industrial Expansion

Canada's industrial growth within the span of the past two decades has been one of the economic marvels of this century. With a population even today of less than 15 millions, Canada has grown to be the sixth ranking industrial power and the third greatest trading nation of the world. In value of Gross National Product per capita, Canada stands second only to the U. S.; in trade per capita, it is exceeded only by New Zealand. For a decade it has been the world's leading exporter of nonferrous metals. In 1951, for example, Canada exported nickel, zinc, aluminum, copper, and lead to a value of $478,000,000, a record never approached by any other country. Canada now leads the free world in production of nickel, platinum and platinum metals, titania slag, newsprint, and asbestos; it stands second in production of aluminum, gold, and cadmium metal; is third in output of zinc, silver, and cobalt, and fourth in copper and lead. Developments now underway promise to place Canada among the front ranks of the world's producers of petroleum, natural gas, and ores of iron, tungsten, and uranium. But not only as a primary producer is Canada's record outstanding; manufacturing has also advanced on a broad front and Canada has become a leading exporter of a number of manufactured articles. Gross value of manufacturing production in 1951 was over $16 billion, more than four times the 1939 value. Further evidence of Canada's remarkable record of growth is presented in Table I.

Canada's extractive and manufacturing industries received a great impetus during World War II, when the nation's productive capacity was strained to the utmost to supply materials sorely needed by the Allied countries. Thus Canada in these years produced nickel, copper, lead, and zinc to a total value of about one billion dollars, for a time supplied close to 40 per cent of the Allied requirements of aluminum, as well as much desperately needed calcium carbide and ferroalloys—to mention only a few products. Yet, while undoubtedly strongly stimulated by wartime exigencies, Canada's bourgeoning economy has proven to have sound foundations in the years of relative peace that have followed. In many respects, Canada's industrial growth has been even more spectacular since the end of the war than during it. Ample proof of this may be found in the statistics of Table I. Since 1948, the combined physical output of nickel, copper, lead, and zinc has increased some 28 per cent, gold 25 per cent and silver 51 per cent, and iron ore 289 per cent. From 1946–52, petroleum refining capacity almost doubled; use of crude oil of Canadian origin increased over eightfold; and in 1952 new discoveries of gas and oil occurred in Canada at the rate of one every two days. The value of metallic minerals produced in 1952 was about $727,916,000, just 2½ times the 1946 value.

TABLE I

	Gross national product at market prices	Physical volume of production 1935–1939 = 100		
	Million dollars	Index of all industrial production	Index of manufactures	Index of chemicals and allied products
1939	5,707	109.3	107.8	112.7
1946	12,026	171.9	189.9	237.7
1948	15,613	196.3	215.5	243.2
1949	16,462	199.6	217.0	239.9
1950	18,122	211.5	228.1	253.7
1951	21,241	226.5	242.1	267.8
1952	22,984	232.9	246.2	272.4
1953 (May)	—	257.4	272.7	—

In the chemical and allied products group, which includes many electroproducts, output at $806,200,000 was over five times the 1939 value and more than double the 1944 wartime peak (not corrected for inflated prices). Capital expenditures in this group of industries from 1946–53, inclusive will total about $630 millions, of which some $370 millions appear in the last three years.

During the period under review, the population of Canada has increased at a far slower rate than industrial production, being 14,692,000 on March 1, 1953, as against 12,292,000 in 1946, and 11,267,000 in 1939.

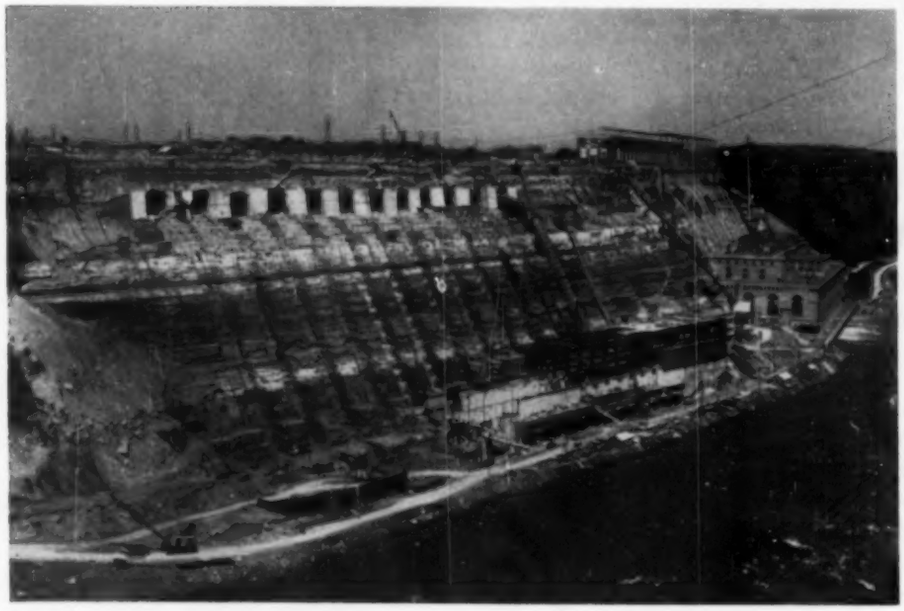
Thus, measured by almost any yardstick, the record of rapid industrialization that has occurred in Canada over this period is truly impressive.

Importance of Electroproducts in Canada's Economy

It is generally acknowledged that Canada's electrochemical and electrometallurgical industries have contributed in great measure to her extraordinary industrial growth. The example

[1] This article, and two succeeding articles on Canada, have been provided for the JOURNAL by A. C. Holm, Canadian Regional Editor.

[2] President, Shawinigan Chemicals Limited, Montreal, Quebec.



Superstructure of the ultramoder powerhouse at Ontario Hydro's 1,200,00 horsepower development takes shape a the base of the 300-foot cliff on the lowe Niagara Gorge. The new development the Sir Adam Beck-Niagara G.S. No. 2 is scheduled for initial service in 195 with six units in operation. Five mor units will be placed in service in 1955 an the remaining one in 1956. The structur at the right is the 525,000-horsepowe Sir Adam Beck-Niagara G.S. No. which was placed in operation in 1922.

TABLE II. *Production of typical electroproducts in Canada*
1,000's of net tons

Year	Silicon carbide (crude)	Fused alumina (crude)	Ferro-alloys	Chlorine	Aluminum ingot	Refined zinc	Refined copper	Refined lead
1935	18.5	51.2	63.4	—	23.2	149.5	173.3	163.8
1939	17.2	51.1	85.5	—	82.8	175.6	231.7	190.6
1940	24.6	85.3	149.4	—	109.1	185.7	261.9	220.1
1945	45.4	133.2	171.6	—	215.7	183.3	228.9	163.1
1946	50.0	119.2	139.4	—	194.1	185.7	167.2	165.7
1947	51.7	146.4	227.1	—	299.1	178.3	202.4	162.0
1948	52.9	144.8	232.7	—	367.1	196.6	221.3	160.0
1949	46.4	113.2	202.1	96.0	369.5	206.0	226.1	146.1
1950	44.8	126.9	180.5	131.0	396.9	204.4	238.2	170.0
1951	70.3	195.4	250.9	155.0	447.1	218.6	245.5	162.0
1952	—	—	232.0	169.5	499.8	223.1	197.0	177.4

Other Products—(Approximate and unconfirmed):

Magnesium, Calcium metal	1952	2307 tons total
Cobalt	(1951)	475 tons
Tin	(1951)	173 tons
Calcium carbide	(1950)	400,000 tons

of aluminum is of itself almost sufficiently spectacular to win such recognition for the whole electroproducts industry. But when one attempts to present statistical evidence for the electroproducts industry as a whole in support of such an assertion, the difficulty arises that production figures for many of these products are not available for publication. However, some idea of the growth of these industries may be gleaned from the examples listed in Table II. Practically without exception, all of the electroproducts of Canada, a list of which is given in Table III, have undergone a substantial expansion of production during or since World War II, or are about to undergo expansion.

For a few nonferrous metals and ferroalloys, production figures are available or can be estimated from published data. In Table IV an attempt is made to summarize production data for six products which are definitely known to result from electrowinning, electrorefining, or electrothermic operations. In some cases the production figures have had to be estimated, and their accuracy cannot be guaranteed; however, they are sufficiently accurate for our purpose. It will be seen that in the past two years these six items alone have accounted for a production of some 1,400,000 tons annually and a value at the works estimated to be about $550,000,000 per annum. For

TABLE III. *Electrochemical and electrometallurgical product*
(Commercial-scale operations—Canada, 1953)

(A) Electrochemical Products
- Chlorine, Caustic Soda, Hydrogen
- Oxygen, Hydrogen.
- Hydrogen Peroxide.
- Chlorates of Sodium, Potassium, Bromium.

(B) Electric Furnace Products
- Calcium Carbide (for acetylene-based chemicals).
- Calcium Carbide, Cyanamide, Dicyandiamide, Cyanide
- Ferroalloys (ferrosilicon, ferromanganese, ferro-chrome, silicomanganese, ferrozirconium, ferro-phosphorus. Exothermic silicon—and chrome alloys)
- Yellow phosphorus.
- Titanium slag and steel.
- Rock wool.
- Artificial graphite.
- Silicon carbide; other artificial abrasives, and re-fractories.
- Fused alumina.
- Tungsten carbide.
- Steel melting (for castings, ingots, etc. Carbon steel, alloy steels, heat resisting steels, stainless steels. Iron powder for powder metallurgy).
- Sodium silicate.

(C) Metals
1. Electrolytic

Aluminum	Indium
Zinc	Cerium (Mischmetall)
Copper	Bismuth (byproduct)
Lead	Selenium (byproduct)
Nickel	Tellurium (byproduct)
Magnesium	Silver, Gold (byproduct)
Cadmium	Platinum and Platinum Metals*

2. Thermal
- Magnesium
- Calcium
- Cobalt
- Tin
- Titanium (semicommercial)

* Anode slimes containing these are exported for refining; the pure metals are not produced in Canada.

ll of the forty-odd electroproducts listed in Table III a very ough estimate of the total value of production might then be the order of $750,000,000. This would rank the electro- products industry third or fourth among the major manufac- uring industries of Canada, being preceded only by the pulp nd paper, slaughtering and meat-packing, and possibly also y the motor vehicles industries.

Another measure of the stature of the Canadian electro- products' industry is the place taken by these products in the ation's exports. Here again statistics for many of these prod- cts are not available for publication. However, it would ap-

TABLE IV. *Six leading electroproducts—production and exports*

Commodity—year	Production		Exports		Exports		
	Net tons	Value* $ millions	Net tons	Value $ millions	As % of total production	% to U. S.	% to U. K.
1. Aluminum (Primary)							
1950	396,882	113.9	335,726	96.4	85	48	41
1951	447,095	141.2	354,414	112.0	79	30	54
1952	499,810	172.7	412,590	142.7	83	28	62
2. Copper (Electrolytically refined only)							
1950	238,204	111.0	134,244	59.7	55	38	48
1951	245,466	135.6	101,832	59.0	41	28	51
1952	196,985	112.9	113,675	71.4	58	46	37
3. Nickel (Electrolytically refined only)							
1950	68,000*	61.8	66,894	57.6	98	73	18
1951	75,000*	82.3	72,357	75.6	94	67	24
1952	78,200*	83.0	77,058	79.7	99	67	22
4. Zinc (Electrolytically refined only)							
1950	204,367	63.9	146,880	40.6	72	74	24
1951	218,578	87.1	146,132	55.4	67	58	38
1952	223,139	77.9	166,864	61.3	75	43	52
5. Lead (Electrolytically refined only)							
1950	170,023	49.2	116,963	32.5	69	91	7
1951	162,001	59.6	107,157	38.5	66	57	33
1952	177,389	57.3	134,953	42.8	76	78	21
6. Ferroalloys (Electric furnace)							
1950	180,500	25.2	122,479	17.1	68		
1951	250,900	41.2	190,454	31.3	76		
1952	232,000	39.5	179,000*	30.4	77		
Totals							
1950	1,257,976*	452.0*	923,186	303.9	73		
1951	1,399,040*	547.0*	972,346	371.8	70		
1952	1,407,523*	542.3*	1,084,140*	428.3	77		

* Estimated Figures.

pear that of the 40-odd commodities listed in Table III probably less than half a dozen are not exported in part from Canada; this does not take into account the dozens of deriva- tives of these main products, many of which are also exported. Referring again to Table IV, the six electroproducts listed represent an export tonnage of about 1,000,000 tons annually, with a declared value of about $372 million in 1951 and about $428 million in 1952. Making a very rough guess as to the ex- port values of all the other Canadian electroproducts listed in Table III, a conservative estimate of the total export value of all electroproducts would be in the order of $500–$600 million. Accordingly, the electroproducts group would easily take third place among the various classes of commodities exported from Canada. This is shown in Table V, wherein are named the commodity groups as listed under Foreign Trade in the Canada Year Book, with a new group, "Six Leading Electroproducts," inserted which comprises only the six elec- troproducts listed in Table IV. Products of forest and farm lead by a wide margin, accounting for some two-thirds of Canada's exports; this is not surprising in view of the coun- try's tremendous output of newsprint, woodpulp, lumber, wheat, and the like. But of all remaining exports (not of forest or farm origin) the electroproducts group (as a whole) would appear to account for almost one-half of the value.

TABLE V. *Summary of all domestic exports from Canada—1950–52* ($ Millions—Declared values)

Commodity group	1950	1951	1952
1. Wood Products and Paper	1,112.9	1,399.1	1,366.8
2. Agricultural, Animal, and Fishery Products	990.5	1,213.2	1,421.4
3. Six leading Electroproducts	303.9	371.8	428.3
4. Iron and Steel and their products	256.2	319.0	376.6
5. Nonferrous Metals and their products	170.5	229.4	308.8
6. Nonmetallic Minerals and products	103.7	131.5	143.5
7. Chemicals and Fertilizers	100.5	131.7	124.6
8. Miscellaneous items	50.7	81.9	103.4
9. Fibers and Textiles	29.6	36.9	27.7
Total value of all domestic exports	3,118.5	3,914.5	4,301.1

Notes

Group 3. Comprises: Primary Al; Electrolytic Cu, Ni, Zn, Pb; Ferroalloys.

Group 4. Except Ferroalloys. Steel melted in electric furnaces is included here.

Group 5. Except 5 electrometals included in Group 3. Other electrometals are included here.

Group 6. Includes artificial abrasives and possibly other electroproducts.

Group 7. This group includes calcium carbide and derivatives and other electroproducts.

It should perhaps be again emphasized that the figures shown for electroproducts in Tables IV and V refer to only six out of the 40-odd electrochemical and electrometallurgical products made in Canada. Also, in the case of the five non- ferrous metals listed, the production and export figures given apply only to that portion of the total production of these metals which is electrolytically refined or produced.

Further strong evidence of the important role played by electroproducts in the Canadian economy are the following facts. Among her electroproducts industries Canada numbers:

1. The world's largest aluminum smelter, at Arvida, Que- bec. A second smelter, which may well outgrow Arvida eventu- ally, is now under construction at Kitimat, British Columbia (Aluminum Company of Canada).

2. The world's largest electrolytic zinc refinery, at Trail, B. C. (Consolidated Mining and Smelting Company).

3. The world's leading electrolytic nickel producer (Inter- national Nickel Company).

4. The world's first electric smelter for titanium slag and steel, at Sorel, Quebec (Quebec Iron and Titanium Corpora- tion).

5. The world's largest cyanamide-ex-carbide plant, and the only one of its kind in North America (North American Cyanamid Company at Niagara Falls, Ontario).

6. The world's largest crude silicon-carbide plant, at Shawinigan Falls, Quebec (Canadian Carborundum Company).

7. Artificial abrasives plants which produce 85 per cent of North American supplies of crude abrasives (6 major producers in Ontario and Quebec).

8. The largest calcium carbide-acetylene products plant in the British Commonwealth, at Shawinigan Falls, Quebec (Shawinigan Chemicals Limited).

9. The world's largest producer of selenium and tellurium metals (Canadian Copper Refiners, Montreal East, Quebec).

Finally, indirect evidence of the magnitude of the electroproducts industry in Canada is the fact that Canadian industry consumes per capita more electrical energy than any country in the world except Norway. In the Province of Quebec, which leads all other Canadian Provinces in electrochemical and electrometallurgical output, the consumption of kilowatt hours per capita is larger than in any other area of the world. This subject will be discussed more fully in the following section.

Aerial view of Arvida Works of Aluminum Company of Canada Limited.

Power in Abundance

In 1952, Canada generated about 69 billion kilowatt-hours of electric power. That was about the same as the United Kingdom, which has three times the population. Only the United States, with its more than 400 billion kilowatt-hours, and the Soviet Union, which is believed to have produced about 100 billion, had greater supplies.

More than 95 per cent of that electricity in Canada was generated from water power. Nearly 90 per cent, too, was produced by central electric stations contributing to the public supply, rather than by industries for their own use. More than half of the total was generated by investor-owned utilities rather than by government-owned systems—which are almost entirely provincial or municipal, since the federal government's ownership of water power is confined almost wholly to the Yukon and Northwest Territories.

At the beginning of this year, with an installed capacity of 14,770,000 horsepower, Canada had developed just a little more than 20 per cent of her known water-power resources—a total of 65,400,000 horsepower commercial potential—and had hardly begun to use, for generation of electricity, her v resources of oil, natural gas, coal, and nuclear materials. N ture has been thoughtful, too, for the very provinces wh have low water-power potentials are those which have their doors the richest supplies of fuel for thermal generati of power.

Much of the yet untapped water power lies within econom distance, even under present transmission techniques, of already established industrial areas. But much of it, too, lies the north in areas yet unsettled or sparsely populated, a that reserve of power is being counted upon to speed the d velopment of the mineral wealth and other resources in t northland, from coast to coast.

From the beginning of World War II up to the end of 19 Canada's installed generating capacity increased by about per cent and her actual annual production of electricity about 120 per cent.

Since the war, the installations added have approache 1,000,000 horsepower each year. In hydroelectric station alone, the additions are expected to exceed 880,000 hors power in 1953, at least 895,000 in 1954, another 900,000 i 1955, and still another 615,000 in 1956. Those figures cove only the projects which are at present actually under constru tion or definitely planned; they do not include such propose immense developments as the St. Lawrence seaway powe plan, or the diversion of headwaters of the Yukon.

Table VI lists, by provinces, the total commercial potenti of water-power resources, the installed hydroelectric capacit as at the beginning of 1953, the hydro additions then under way, and the installed thermal-plant capacity.

Table VII shows Canadian production as in 1951, in tota and per capita, compared with other nations in the generatio of electricity.

Table VIII illustrates the electrical production which Canada draws from her installed capacity, equal to more tha one horsepower per capita, and the low cost of that produc tion as reflected in selling prices per horsepower and per kwh

The federal bureau of statistics, remarking in an official bulletin that the nation enjoys about the lowest average elec trical costs in the world, says that in 1951 the average domes tic consumer paid 1.6 cents per kwhr in Canada, as against 2.8 cents in the United States, while the average rate to com

rcial and industrial customers was 0.6 cents in Canada and cents in the United States.

Three principal factors make possible this inexpensive elec-city, despite Canada's relatively scattered population and nsequent distribution costs. Those factors are the very high portion of low-cost hydroelectric power rather than ther-l; the favorable natural conditions of topography and ecipitation which make construction and operation rela-

TABLE VI. *Electric Power in Canada—1/1/53* (In thousands of horsepower)

Province	Hydro			Thermal installed
	Total potential	Installed	Under constr.	
wfoundland	3,360	286.7	24	4.2
nce Edward Is.	4	2.3	—	21.7
va Scotia	203	162.4	9	153.5
w Brunswick	433	135.5	27	90.5
uebec	26,285	7,250.4	931	2.5
ntario	9,440	4,400.5	1,238	605
anitoba	7,230	735.9	80	22.1
askatchewan	1,455	111.8	—	276
lberta	1,630	207.8	53	223
ritish Columbia	14,300	1,444.8	817	29.9
ukon & NWT	1,060	31.5	1	1.4
anada	65,400	14,769.6	3,180	1,429.8

TABLE VII. *Production of electricity—1951*

	Millions of kwhr	Kwhr per capita
anada	62,500	4,470
Quebec	30,620	7,500
Ontario	18,930	4,100
British Columbia	4,700	3,900
Prairie Provinces	4,570	1,760
Maritime Provinces	2,180	1,680
nited States	432,320	2,800
viet Union (estimated)	100,000	500
nited Kingdom	60,000	1,185
est Germany	51,300	1,070
apan	41,200	480
rance	36,000	850
taly	29,400	635
weden	19,200	2,750
orway	17,360	5,250
nion of South Africa	11,680	920
ustralia	10,500	1,200
witzerland	10,250	2,160
oland	9,950	400
elgium	9,450	1,100
pain	7,200	257
etherlands	5,800	570
ustria	5,650	820

tively economical even for hydro plants; and the fact that large proportions of the electricity produced go in large blocs to industrial consumers. Almost one-fifth of the total output goes to the pulp and paper industry, and one-sixth to smelting and refining of metals.

In all, about two-thirds of Canada's gross production of electric power goes to industry. Table IX gives, as of a while ago, the approximate division of that proportion between the leading divisions of manufactures, and the all-Canada estimated average cost in each, in cents per kwhr.

Here, in order of consumption, are the general requirements, in kilowatt-hours, for the production of various electrochemical and electrometallurgical products:

Aluminum, 24,000; Magnesium, 20,000; Nitrogen (Cyanamid process), 15,000; Silicon Carbide, 9,000; Ferroalloys, 4,000–8,000; Graphitized products, 3,000–8,000; Zinc (Electrolytic), 4,000; Caustic Soda and Chlorine, 3,400; Alumina (Fused), 3,200; Calcium Carbide, 3,000; Cadmium, 2,500; Steel Furnaces, 600; Copper Refining, 400.

All of these processes are used, most of them extensively, in Canada now. Other processes which will require vast quantities of power are nearing full development—and low-cost hydroelectric power awaits them in Canada.

TABLE VIII

Province	Production, 1952 (million kwhr)		Average price (centrals) 1951	
	Industrial	Central	$ per hp year	¢ per kwhr
Newfoundland	1,000	171	37.68	1.6
Prince Edward Island	—	28	56.29	3.7
Nova Scotia	160	955	45.31	1.6
New Brunswick	360	741	54.29	1.3
Quebec	900	32,142	20.42	0.4
Ontario	2,200	18,169	29.53	0.7
Manitoba	8	2,696	32.48	0.6
Saskatchewan	3	1,073	37.31	1.4
Alberta	12	1,146	50.74	1.8
British Columbia	2,600*	4,667*	42.86	1.3
Canada	7,243	61,788	29.31	0.6

* Including Yukon and Northwest Territories.

TABLE IX

Manufacturing industry	% Utilization	Kwhr per $ of gross products	Avg. cents per kwhr
Nonferrous Metals	34.4	7.29	0.3
Wood and Pulp	33.8	4.90	0.4
Iron and Steel	10.4	1.26	0.6
Chemicals	8.2	5.21	0.4
Nonmetallic Minerals	6.3	2.24	0.4
Vegetable	2.7	0.38	1.0
Textile	2.4	0.56	0.9
Animal	1.2	0.19	1.3

The second and third articles in this series will treat, in some detail, of the major hydroelectric developments in each area of Canada, both actual and future.

Location and Development of Electroproducts Industries

The establishment of Canada's electrochemical and electrometallurgical industries has proceeded according to three general patterns. The normal procedure has been for an electroproducts industry to move into an area, usually already well populated, where excess hydroelectric power was available at low rates, from existing power developments. The second type of development has been initiated by the discovery of huge ore bodies, usually quite remote from settlements or from fuel supplies, which sooner or later necessitated the harnessing of large water powers in the vicinity for the purpose of electrowinning or electrorefining the metal content of the ore. And, finally, the third, more recent type of establishment has seen the electrometallurgical project preceded

by a deliberate seeking out and developing of new hydroelectric power resources, usually in remote, undeveloped areas, for the express purpose of providing enormous amounts of power at low cost for this one particular project. All three types of development are proceeding in Canada at the present time.

The earliest electrochemical developments in Canada belong in the first category, the result of efforts to exploit local cheap hydroelectric power. This type of development has been responsible for the creation of some of Canada's largest electroproducts centers. The first example of this type was an electrolytic potassium chlorate plant built in the early 1890's near Buckingham, Quebec. This was superseded in 1896 by an electric furnace phosphorus plant, to which was added in 1898 the production of ferrochrome from Quebec ores. Today, the Electric Reduction Company of Canada Limited is carrying on the production of electric furnace phosphorus, ferrophosphorus and mineral wool, as well as electrolytic chlorates, at Buckingham, Quebec.

Some of the 80-odd buildings in the plants of Shawinigan Chemicals Limited at Shawinigan Falls, Quebec. Starting with limestone from its own quarries, coal and coke, and hydroelectric power these plants produce carbide, acetylene and a long list of organic chemicals, as well as acetylene black, resins, and stainless steel.

In the decade beginning 1900, large-scale electrochemical and electrometallurgical developments took place in Canada, mainly due to the availability of lost-cost hydro power generated at Niagara Falls, Ontario, and at Shawinigan Falls, Quebec. In this period there were built large plants for the production of calcium carbide, cyanamide, ferroalloys, artificial abrasives, and chlorine in the Niagara area, and aluminum and calcium carbide at Shawinigan Falls. Today the Niagara district produces such electroproducts as carbide, cyanamide, cyanide, sodium silicate, ferroalloys, artificial abrasives and refractories, artificial graphite, electrolytic nickel, rock wool, and electric steel. At Shawiningan Falls, on the St. Maurice River in Quebec, Canada's first aluminum smelter started operations in 1901, coincident with the first hydroelectric development of the Shawinigan Water and Power Company at this site. In the same year the Shawinigan Carbide Company was formed, which has since become Shawinigan Chemicals Limited. Besides aluminum and calcium carbide, Shawinigan Falls now produces also silicon carbide, chlorine, caustic soda and hydrogen, hydrogen peroxide, cerium (mischmetall), and electric steel, as direct electroproducts, besides many derivatives. Another large electroproducts center has grown up around the more recent huge Beauharnois hydroelectric station on the St. Lawrence River near Montreal. Here there are located two plants producing ferroalloys, an aluminum smelter, and a chlorine caustic soda plant.

Besides the four major electroproducts centers named above producing more than one type of product, there are a large number of other localities where a single type of operation is carried on, which may be grouped in our first category, i.e., of projects set up to utilize existing low-cost power. Here may be mentioned Sault Ste-Marie, Ontario, where the Chromium Mining and Smelting Corporation Limited produces ferrochromium, ferrosilicon and various exothermic silicon, and chrome alloys. At Windsor, Ontario, Canadian Industries Limited produces caustic soda, chlorine, and hydrogen, and operates another plant at Cornwall, Ontario, for these same products. At Montreal East, in Quebec, Canadian Copper Refiners Limited produce electrolytic copper with selenium and tellurium as byproducts. At

Varennes, Quebec, on the south shore of the St. Lawrence River east of Montreal, a new plant of the Electric Reduction Company of Canada is about to go into operation to produce electric furnace phosphorus. A few miles further east at Sorel, Quebec, the Quebec Iron and Titanium Corporation has brought a new electric smelting plant into operation to produce titanium slag and steel from ilmenite ore. At Cap-de-la-Madeleine, at the confluence of the St. Maurice and St. Lawrence rivers, new production facilities have sprung up in recent years for artificial abrasives (Electro Refractories and Abrasives Canada Limited, and Norton Company) and for iron powder (Ferrum Limited). These latter plants, east of Montreal, receive their power from the six hydroelectric developments on the St. Maurice River of the Shawinigan Water and Power Company.

In this first group of industries we should perhaps also include chlorine plants operated by paper mills for their own purposes, i.e., bleaching of pulp. Such plants are to be found at Marathon, Temiskaming, Espanola, and Cornwall, all in Ontario. Dow Chemical of Canada operates a chlorine plant at Sarnia, Ontario, and the Aluminum Company of Canada one plant at Arvida, Quebec. Four other chlorine

plants were mentioned earlier, viz., Windsor and Cornwall in Ontario and Beauharnois and Shawinigan Falls in Quebec. The eleventh and latest chlorine plant in Canada is being built at Duvernay, Alberta.

And finally, an important member of this first category of electroproducts industries set up to utilize available low-cost power is the electric steel melting furnace. In 1952 about 8 per cent of Canada's steel for ingots and castings was melted in electric furnaces. There are some 83 electric steel furnaces operated by 36 different firms scattered across Canada; of these furnaces about 42 are located in Ontario, 33 in Quebec, and 11 in British Columbia.

The foregoing examples show clearly how the availability of low-cost hydroelectric power has been responsible for the establishment of a great many electroproducts industries in Canada. In many cases these industries are turning out products far in excess of Canada's requirements; a few are using imported raw materials. It is highly probable that many of these projects would never have been set up in Canada at all had not large quantities of dependable, inexpensive electric power been available from existing developments.

Turning now to the second group of electroproducts developments, those initiated primarily by the exploitation of ore deposits rather than of hydroelectric power resources, the earliest and most outstanding example is that of the Consolidated Mining and Smelting Company at Trail, British Columbia. Availability of tremendous supplies of lead-zinc ore in the area, nearby hydroelectric power resources, and access to coke have made Trail one of the leading chemical-metallurgical centers of the world. This company now produces zinc, lead, cadmium, bismuth, gold, silver, and indium by electrolytic separations or refining, and tin by an electrothermal process. At Trail "Cominco" also operates a large plant for electrolytic hydrogen and oxygen. Low-cost hydroelectric power for these processes has been obtained from a series of developments on the Kootenay River.

Another striking example of the use of electrometallurgy in exploiting ore-bodies is provided by the International Nickel Company of Canada, Limited, which produces electrolytically refined nickel, copper, silver and gold, and partially refined mixtures of the platinum metals from its huge copper-nickel ore deposits in the Sudbury area of Ontario. This company in 1952 supplied over 75 per cent of the nickel used by the free world. "Inco's" electrolytic nickel refinery is located at Port Colborne, Ontario, while the electrolytic refining of blister copper and the major smelting operations are carried on at Copper Cliff, Ontario.

To this second group of electrometallurgical developments belongs also the electrolytic zinc plant of the Hudson Bay Mining and Smelting Company Limited at Flin Flon, Manitoba. Located only slightly south of the 55th parallel near the Saskatchewan-Manitoba border, it is the most northerly of Canada's electrometals industries. Blister copper from the Flin Flon smelter goes to Montreal East in Quebec for electrolytic refining. A hydroelectric development on the Churchill River makes possible the production of electrolytic zinc at Flin Flon, which has been carried on since 1930.

Two other electrometallurgical projects based primarily on local mineral deposits rather than on existing power supplies may be mentioned: that of Dominion Magnesium Limited at Haley, Ontario, and the recently completed plant of Kennametal of Canada Limited in British Columbia. The former utilizes local dolomite deposits to produce high purity magnesium by the Pidgeon process in high-vacuum retorts heated in electric resistor furnaces. Dominion Magnesium Limited also produces high-purity calcium metal in the same plant, and has produced other metals experimentally, notably titanium. In British Columbia, where important tungsten ore bodies are being developed, Kennametal of Canada Limited has begun electric furnace smelting of tungsten ore to produce tungsten carbide; this plant is located at Port Coquitlam, British Columbia.

Smelters and other plants of the Consolidated Mining and Smelting Company at Trail, B. C.

Attention has recently been given to the possibility of producing electric furnace pig iron from iron ores in British Columbia and from the huge deposits of the Iron Ore Company of Canada and of Fenimore Iron in the Ungava region of Quebec. The latter area offers a large potential of hydroelectric power. However, little is known as yet of the economic feasibility of such possible developments, which are under study by various interests.

In the third category of electrometallurgical establishments in which the characteristic feature is the development of

huge hydroelectric power facilities for the exclusive use of the new project, the outstanding and, as yet, only example in Canada today is that of the Aluminum Company of Canada Limited. It has previously been mentioned that the first smelter of this company was set up at Shawinigan Falls, Quebec, in 1901 to take advantage of a power site developed there by the Shawinigan Water and Power Company. During World War II another smelter was established at Beauharnois, Quebec, an additional smelter at Shawinigan Falls, and a third at La Tuque on the St. Maurice River to use power available at those sites; the La Tuque smelter has since been dismantled. In the early 1920's it became apparent that the growing demand for power on the St. Maurice River on the part of other consumers would limit the amount available for aluminum. The Aluminum Company, therefore, began in 1925 a new development of its own in the Saguenay Valley of Quebec, where a large power potential existed. This area, at that time devoted mainly to farming and forestry, has since become the largest aluminum producer in the world, with smelters at Arvida and Isle Maligne, near the outlet of Lake St. John. The combined capacity of the company's present four smelters in Quebec accounts for nearly 25 per cent of the world's production of primary aluminum. Arvida now also produces caustic soda and chlorine and magnesium metal by electrolytic methods as further operations of the Aluminum Company, and fused alumina in a plant of the Simonds Canada Abrasive Company Limited, making this one of the large electroproducts centers of Canada.

But so tremendous is the world's demand for aluminum and so vital the supply of huge amounts of low-cost power for its production, that the Aluminum Company of Canada has now embarked on another combined power and smelter project, this time some 400 miles north of Vancouver, British Columbia, at Kemano and Kitimat in entirely undeveloped country to harness the approximate 2,000,000 hp obtainable there.

While the Aluminum Company of Canada presents the only existing examples of such large-scale moves into the northern wilderness in search of cheap power, there is evidence that other firms are thinking along the same lines. The Ventures-Frobisher Limited interests are reported to be investigating an area along the Yukon-British Columbia border of the Upper Yukon River where some 4–5 million hp are believed to be obtainable from relatively low-cost, successive hydro developments not too far removed from ice-free tidewater. Speculation is rife that such developments may give rise to a chain of smelters capable of treating ores from the Yukon, Alaska, and coastal British Columbia areas as well as imported foreign ores, to yield such products as iron and steel, ferroalloys, and cobalt. It has been reported that a 25,000 hp "pioneer" plant is to be installed by late 1955; however, no fixed plans have been announced as yet.

Future Opportunities

What the future may hold in store for Canada's electroproducts industries cannot be forecast, but there would appear to be no known obstacles in the way of a continuing development for the remainder of this century that will match or surpass the achievements since 1900. All the prerequisites seem to be met: abundant raw materials, alert technology, a growing demand for the products, good transportation facilities, and, above all, abundant, inexpensive power. It is estimated that only about one-half of Canada's land area has received adequate mineral exploration; recent discoveries of tremendous reserves of petroleum, natural gas, iron ore and ilmenite ore, and important widespread indications of base metals, plus tungsten and uranium, point to the potentialities. Accumulated "know-how" is extensive and sound; many important technological "firsts" have been achieved in Canada, e.g., world's first commercial electrolytic lead, North America's first cyanamide and magnesium plants. The world's need for high-purity metals as well as other electro products is constantly growing as known mineral deposits become depleted and electric power shortages develop in countries other than Canada. This is especially true of Canada's closest neighbor and best customer, the United States. The Paley Report has clearly underlined the growing dependence of the United States on other countries for many minerals. Table IV in this article shows that of six leading electroproducts of Canada from 40–99 per cent of total production is being exported, of which 30–90 per cent is going to the United States. Canada possesses well-developed railway and steamship facilities for the movement of raw materials and products, and the expected imminent deepening of the St. Lawrence Seaway should improve shipping possibilities. As for electric power, notwithstanding the very active development of hydro resources in the past, over 75 per cent of Canada's commercially economic hydroelectric resources lie undeveloped, in all about 50,000,000 hp. Some of this can be made available to the present heavily industrialized areas at relatively low rates, while other more remote resources may be used near their sites by developments such as we have seen at Flin Flon and Kitimat. And thermal power may play a larger role in the future, with the development of Western Canada's huge oil and natural gas reserves and their long-distance transmission by pipelines, which is just beginning, and the extensive mechanization of coal mining on Canada's eastern seaboard. In such long-range forecasting, the possibilities of atomic power and even of tidal power in some locations, while today seemingly remote, should not be overlooked.

Two minor flaws mar this almost perfect picture of future possibilities—high tariffs on some products entering the United States, and import restrictions in many overseas nations. Yet Canada is confident that its enormous reserves of raw materials and electric power available at relatively low cost, and the pressing needs of other nations, will obliterate these barriers to trade.

In electroproducts, Canada indeed can claim a substantial share of the twentieth century!

NOTE: In the second article of this series, it is proposed to deal in some detail with individual electroproducts industries and power developments in Quebec, the Maritime Provinces, and Newfoundland, while the third article will discuss such developments in Ontario and the Western Provinces, including the Yukon and the Northwest Territories.

electrodes placed in two sodium chloride solutions of different activity which are separated by an ion-exchange membrane, sodium chloride is transferred from the concentrated solution to the dilute one. Since the electroosmotic transport of water is in the same direction, water is simultaneously transported from a solution more dilute with respect to water to a more concentrated one. The electroosmotic transport therefore decreases the ideal membrane potential. The general equations for the electromotive force which take solvent transport into account have been developed and discussed by Scatchard (58). The complete expression for the membrane potential, dE, between two solutions of sodium chloride of activity a and $a + da$ is

$$dE = \frac{RT}{\mathbf{F}} [-d \ln a_{Na} + (T_{Cl} + 0.018 m'_{Cl} T_W) d \ln a_{Na} a_{Cl}]$$

where T_{Cl} and T_W are the number of moles of chloride ion and of water transported per Faraday, and m'_{Cl} is the molality of the solution with respect to sodium chloride. The first term on the right side represents the contribution of the transport of sodium ions to the potential, the second that of the chloride ions in the resin, and the third is due to the electroosmotic transport of water.

The occurrence of electroosmosis explains why the values of ionic self-diffusion coefficients computed from the specific conductance by the Nernst-Einstein formula are lower than those measured directly from the spread of radioactive tracers. When the mobile cations migrate under the action of an electric field, their linear velocity with respect to the fixed anions is higher than with respect to the electroosmotic flow of water. Therefore, the measured conductance, k, is higher than the conductance, k^*, corresponding to a state where the water is at rest with respect to the fixed anions. When self-diffusion occurs in a resin, no electroosmosis takes place, and hence if k instead of k^* is used to calculate the self-diffusion coefficient by the Nernst-Einstein formula, the computed values are too high.

Since the electroosmotic permeability of an ion-exchange membrane (in ml water transported per volt and second), L_{EP}, is a measure of the frictional force between the water molecules and the resin through which they migrate, it is related to the hydraulic permeability, D_H, (in ml solvent passing through the membrane per second and pressure difference of one dekabar; 1 dekabar $\equiv 10^7$ dynes/cm^2) which also depends on this force. (D_H refers here to the permeability measured in the absence of a streaming potential.) L_{EP} is also related to the electrical conductance, L, (in mho) of the membrane, because the latter, in turn, is related to this frictional force. The relationship between electroosmotic permeability, hydraulic permeability, and conductance appears in the general equations for the flow of current, I, and water, V, through a membrane between two solutions to which both an electrical potential, E, and a pressure differential, P, are applied. It can be shown by elementary considerations (63, 64) or in a quite general manner by the methods of the thermodynamics of irreversible processes (67, 68) that the same membrane constant, L_{EP}, appears in both equations:

$$I = LE + L_{EP}P \qquad \text{(XIII)}$$

$$V = L_{EP}E + D_H P \qquad \text{(XIV)}$$

where I is the current through the membrane (amp), E the potential applied to it (volt), P the pressure difference between the two sides of the membrane (dekabar), and V the flow of water through the membrane (ml sec^{-1}).

The first equation states that the current flowing through the membrane is composed of two parts, namely, the regular current which is proportional to the applied electrical potential, and a convection current proportional to the pressure difference. The second equation states that the water flow through the membrane is composed of the regular flow, proportional to the pressure difference and the electroosmotic flow, proportional to the applied electrical potential. Each of these statements is almost self-evident, but it is important that the same constant, L_{EP}, appears in both equations.

Equations (XIII) and (XIV) are true for any membrane model. Schmid (40) has shown that if the membranes are considered as one-phase systems rather than a network of microscopic pores (sponge model), the following simple relation holds between L_{EP} and D_H:

$$L_{EP} = \mathbf{F} A D_H \qquad \text{(XV)}$$

where $\mathbf{F}$ is Faraday's constant (coul.eq^{-1}) and A the molal resin capacity (eq. per ml water). It is assumed that the active groups in the resin are completely ionized and that their electrostatic interaction is negligible. If this is not so, A must be replaced by $f_\lambda A$, where f_λ is the conductivity factor

By means of equation (XV) it is possible to obtain a rough estimate of the electroosmotic permeability of resinous membranes from their hydraulic permeability and vice versa, provided the molal resin capacity is known. Moreover, if the conductance of the membrane is known, all other electrokinetic properties such as streaming potentials and streaming currents can then be calculated by combination of equations (XIII), (XIV), and (XV).

It is known that the hydraulic permeability of commercial synthetic ion-exchange membranes is very low, but only few quantitative data are available. Rosenberg (66) reported that the specific hydraulic permeability[4] of Nepton CR-51 membrane in the sodium form at room temperature was 2.3×10^{-7} cm^2 dekabar^{-1} sec^{-1}. This value was obtained by measuring the flow of water through a membrane under a pressure differential but without applying an external short circuit between the solutions on the two sides of the membrane. It is much lower than the specific hydraulic permeability of the collodion membranes used by Schmid (63, 64). The capacity of the membrane was about 0.002 eq. per ml water. If it is assumed that the conductivity coefficient, f_λ, equals 0.5, which is a reasonable value at this molality, modified equation (XV) yields the value of 2.2 volts^{-1}cm^{2}sec^{-1} for the specific electroosmotic permeability. Since the specific conductivity of the membrane was 0.008 mho cm^{-1}, the time necessary to pass one Faraday was 1.21×10^7 sec, and hence the amount of water transported was 265 ml per Faraday, while direct measurement of the electroosmotic transport gave a value of 300 ml (66). The agreement is rather good in spite of the crudeness of the estimate of f_λ and of the use of a permeability value uncorrected for the "electroviscous effect" (63), resulting from the absence of an external short circuit. (In these calculations ml and cm^3 were set equal.)

Practical Applications of Ion-Exchange Membranes

These researches provide the theoretical background for the application of ion-exchange membranes as ionic sieves which are able to screen out one charge-type of ions. The use of ion-exchange membranes for electrodialysis processes of this kind offers a number of promising possibilities. So far,

[4] The specific hydraulic permeability is defined as the flow of water (in ml sec^{-1}) through a membrane cube 1 x 1 x 1 cm and per pressure difference of 1 dekabar.

only little work has been published on practical applications of these membranes, but it is believed that considerable effort is being expended in this field (69, 69a, 69b, 70).

For instance, salt removal from sea water or other brines can be effected by electrolysis of systems of the following kind:

Inert anode, solution	anion-exchange membrane	middle chamber: sea water	cation-exchange membrane	solution inert cathode

If a current is passed, the anions and cations will move from the middle chamber to the anion and cation chambers, respectively, while almost no movement of anions from the cathode to the middle chamber or of cations from the anode to the middle chamber is possible, because of the selective permeability of the cation and anion-exchange membranes for cations and anions, respectively. Hence the sea water in the middle chamber is being demineralized.

Similar systems containing less permselective membranes had been used previously to produce electrolyte-free water from tap water (72, 73).

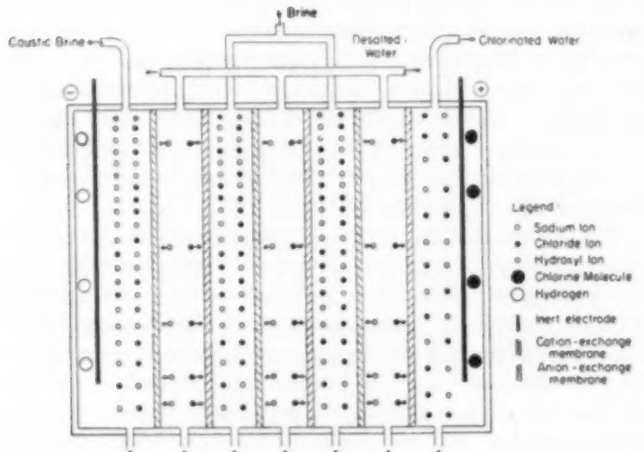


FIG. 7. Schematic representation of salt removal from brackish water in a multicompartment electrodialysis cell containing ion-exchange membranes.

The thermodynamic minimum requirement of electrical energy to reduce the salinity of 1000 gal of sea water containing about 3.5 per cent dissolved salts by a factor of one hundred, i.e., to a drinking water level is about 2.5 kwhr. This value corresponds to the free energy of the dilution process and, therefore, refers to a completely reversible process. In practice, electrical energy is always lost by irreversible transformation into Joule heat and as a consequence of processes occurring at the electrodes. For instance, in a representative experiment, a magnetite anode and a nickel cathode were used, and the potential drop at the electrodes alone was found to be about three volts (73). A portion of the energy corresponding to this potential drop is required for the electrode reactions, in this case the following:

$$\text{Anode: } Cl^- = \tfrac{1}{2}Cl + e^- \text{ or } 2OH^- = H_2O + \tfrac{1}{2}O_2 + 2e^-$$

$$\text{Cathode: } Na^+ + H_2O + e = NaOH + \tfrac{1}{2}H_2.$$

The rest is due to irreversible electrode processes which cannot be reduced below a certain minimum. It is hard to prepare completely reversible electrodes giving a sufficiently long period of useful service.

However, improved power economy can be achieved by passing the current through a series of cells separated by alternating anion and cation-exchange membranes with electrodes only at the terminal points of the series (71) as shown in Fig. 7. In this case, the loss of energy at the electrodes per equivalent of salt removed from the salt water will be reduced to a minimum.

The diffusion of electrolytes into the membranes and electroosmotic water transport play an important part in the power economy of the process. Both reduce the efficiency, the first because it causes some ion transport from the concentrated into the dilute solutions, and the latter because it causes the flow of pure water from the fresh water into the brine compartments. Both effects decrease with increasing crosslinking of the membrane material, but the higher electrical resistance of highly crosslinked ion-exchange resins requires a compromise in the extent of crosslinking (74).

At relatively low production rates, practical energy requirements for this process have been estimated at 20–30 kwhr/1000 gal of fresh water produced (70, 71). The latter figure is only one-third that of the most efficient vapor compression units available. On the other hand, the initial investment may be considerable. Little is known about the stability of the membranes over a considerable period of time. The cost of the fresh water may be determined largely by the development of stable and sturdy membranes.

For the demineralization of waters of lower salinity than sea water, the economical prospects of this process seem attractive even at this stage. An idea about the power requirements and size of such units may be obtained from the following figures for a pilot model offered by one manufacturer (75).

A unit for the demineralization of 200 gal/hr of brackish water containing 2000 ppm (parts per million) of sodium chloride to a level of 400 ppm uses a power input of 0.6 kw. The size of the unit is 4 ft.[3]

Where fresh water and concentrated brine are available, the system shown in Fig. 7, operating in reverse, may be used for the production of direct current, utilizing the free energy of dilution of the brines (76, 77).

The potential E' of each cell unit consisting of a brine compartment, anion-exchange membrane, fresh water compartment, and cation-exchange membrane in series, is given by

$$E' = (T_+^c - T_+^a)\frac{RT}{\mathbf{F}}\ln\frac{a_B}{a_S},$$

because the passage of one Faraday involves the reversible transfer of $(T_+^c - T_+^a)$ moles of NaCl from the brine to the fresh water compartment. a_B and a_S are the activities of NaCl in brine and fresh water, respectively, and T_+^c and T_+^a the average transference numbers of the sodium ion through cation and anion membranes, respectively.

In practice, E' cannot reach high values, because at high values of a_B the membranes lose their permselectivity and $(T_+^c - T_+^a)$ becomes small, while at low values of a_S the inner resistance of the cell is high. It remains to be seen if it is possible to achieve practical results by arranging in series a large number of such cells with very narrow spaces between the membranes, through which brine and dilute solutions flow.

It is also possible to obtain a resinous analogue of the Daniel cell:

$$Cu \mid CuR_2 \mid ZnR_2 \mid Zn$$

whose potential depends on the type of cation exchanger, R, used. Measured potentials were often higher than 1 volt

(18). Permselective diaphragms made of ion-exchange membranes can be used to advantage in primary electric cells. They prevent mixing of anolyte with catholyte, and yet offer little resistance to the passage of the current. Thus an anion-exchange resin membrane in the sulfate form was used to separate the zinc and copper sulfate solutions in a cell of the Daniel type (10a).

Continuous separations of ions in solution can be carried out using the membranes as "ionic sieves" in electrodialysis processes in which selective transmission of ions from one solution to another is desired. For instance, if a potential is applied to a cell containing mixed solutions of sodium and potassium salts separated by a membrane, enrichment of potassium in the cathode chamber will occur. This effect can be magnified by cascading a number of such cells as shown in Fig. 8 (78). This multistage system is analogous to a distillation column with the feeding stock entering at one of the middle plates and with reflux from the cathode chamber. The engineering calculations for such a column are very similar to those developed for stills.

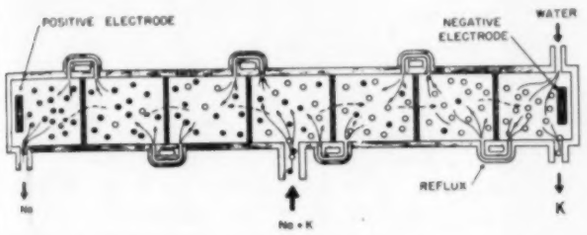


FIG. 8. Continuous separation of sodium from potassium by multistage membrane cell.

Conclusion

Different aspects of the electrochemistry of both cation and anion-exchange resins lead to the conclusion that the solid polyelectrolyte model of the resins is essentially consistent with the electrochemical data. While solid in the gross physical sense, the wet resins act like solutions of electrolytes whose properties are modified by the binding of one charge type of ion to a macromolecular, immobile hydrocarbon matrix. It is reasonable to assume that the development of the electrochemistry of concentrated solutions will be associated with the development of ion-exchange resin theory. There is little doubt, however, that work on practical applications will make headway even before this is achieved.

Acknowledgments

Thanks are due to Professors G. Scatchard and C. D. Coryell for many valuable discussions, and to Professor J. A. Beattie and Dr. M. R. J. Wyllie for their helpful suggestions. This work was partly supported by the Atomic Energy Commission and the Weizmann Institute Postdoctoral Fellowship.

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Current Affairs

Death of Dr. Colin G. Fink

It is with great regret that the JOURNAL records the death on September 16th of Dr. Colin G. Fink, 14th president and for 26 years secretary of The Electrochemical Society and editor of its TRANSACTIONS. A memorial service was held in the Chapel of Columbia University on October 9th.

Colin Garfield Fink was born in Hoboken, New Jersey, on December 31, 1881. After graduation from Columbia University in 1903, he went to Leipzig for graduate study. Here he received the Ph.D. degree with highest honors. Returning to America he joined the research staff of the General Electric Company. In 1917 Dr. Fink became chief chemist for the Chile Exploration Company and he went from this position, in 1921, to Columbia where he became head of the division of electrochemistry. Following retirement from active teaching in 1950, he was appointed emeritus professor of chemical engineering.

Dr. Fink joined The Electrochemical Society in 1907 and immediately became active in its affairs. He published many papers in the TRANSACTIONS over the years. He was elected president in 1918 and became secretary upon the death of Joseph W. Richards in 1921. Upon retirement from the latter office in 1947, Dr. Fink was made Secretary Emeritus of the Society. At a dinner given in his honor during the fall convention in October 1947, Dr. Fink was presented with a scroll in appreciation and grateful recognition of his great services to the Society. On that occasion his many students in all parts of the world presented him with a bound volume of their letters of greeting.

The professional career of Dr. Fink was threefold in character—scientist, educator, and executive secretary-editor. In each, his achievements were notable. Among his best-known research projects were those that led to ductile tungsten for incandescent lamp filaments, an insoluble anode for the electrowinning of copper, an electrolytic process for the faithful restoration of corroded ancient bronzes, the development of hot dipped aluminum coatings, the electrodeposition of metals, and, in particular, a commercial process for chromium plating.

COLIN G. FINK

As teacher to a generation of students, the influence of Dr. Fink will endure for a long time. His infectious enthusiasm, insatiable curiosity, and energetic drive inspired all who came in touch with him. These qualities account for Dr. Fink's great popularity as a teacher. His students have become leaders in science and engineering in this country and abroad, both in academic and industrial circles.

Sharing the early optimism of the founders of this Society, Dr. Fink foresaw the important part that electrochemistry was to play in modern life. This led to his whole-hearted devotion to the purposes and the affairs of the Society. From early morning until late evening, every moment that could be spared from teaching and research was spent on Society matters. Not only secretarial correspondence, bookkeeping, financial reports, meeting arrangements, and Board meetings claimed attention, but editorial problems, translations, revisions, and the styling of manuscripts for the printer were taken care of personally. At no time did Dr. Fink receive a salary or any other form of monetary compensation for his services. When presented with the $1000 Acheson prize in 1933 he promptly returned it to the Society's Roeber Research Fund. A fierce loyalty to the Society and to the profession of electrochemistry seems to have urged him on. He admitted that "Our entire social life was centered around the Society." No one has ever been more intimately identified with the Society and no one ever made a greater contribution to its welfare than Dr. Fink. Without this generous devotion it is doubtful that the organization would have survived in 1921 and during the depression period of the early 1930's. It was the faith and loyalty of Dr. Fink that made continued existence possible.

Beyond the conduct of current affairs, Dr. Fink found time for constructive, longer range matters. Largely through his efforts the Acheson Medal, Weston Fellowship, and the Roeber Research funds were created. He had much to do with the establishment of sustaining membership and personally secured practically all of the first fifty sustaining members.

Among the many honors received by Dr. Fink were the Acheson Medal in 1933 and the Perkin Medal in 1934. He was the recipient of an honorary D.Sc. degree and was elected to honorary membership in The Electrochemical Society in 1946. He was the author of over 200 papers and held many patents.

Dr. Fink leaves a wife, Lottie Muller Fink, and two sons, Dr. Harold K. Fink of New York, and Frederick W. Fink of Columbus, Ohio. To them the Board of Directors has extended a resolution of sympathy on behalf of the Society.—RMB

DIVISION NEWS

Electronics—Instrumentation Symposium Scheduled for Chicago

The Instrumentation group of the Electronics Division will hold its third biennial symposium at the Chicago Meeting, May 2–6, 1954. Emphasis for this symposium will be placed on instrumentation of particular interest to the electronics industry.

Five copies of the abstract (not to exceed 75 words) should be sent to Society headquarters, 216 West 102nd Street, New York 25, N. Y., not later than January 15, 1954.

In addition, the 75-word abstract and a longer abstract of 1000–1200 words (2½–3 double-spaced pages) should be submitted to the Chairman of the Instrumentation Symposium, A. E. Martin, % Sylvania Electric Products Inc., Sylvania Center, Bayside, N. Y., as soon as possible, with a final deadline of January 15, 1954.

The extended abstract of about 1000 words is "*printed, but not published*" in a booklet which will be available, at cost, during the meeting. Abstracts of other Electronics Division papers (luminescence, screen applications, semiconductors, etc.) will also appear in this booklet.

Participation in the 1954 Instrumentation Symposium is cordially invited.

Industrial Electrolytic Spring Meeting Plans

The Industrial Electrolytic Division is planning sessions at the Chicago Meeting of the Society, May 2–6, 1954. As outlined at present, the program of this Division will include a technical session with papers on industrial electrolysis, a business session and luncheon, and a round-table conference on "Compression of Halogen Gases" with special emphasis on the history of chlorine compressors and discussion of types of compressors in use at present. The Division further plans a joint symposium with the Rare Metals group of the Electronics Division and with members of the Electrodeposition Division on "Fused Bath Electrolysis."

Additional papers on any of the above subjects are being solicited. Authors having material appropriate for these sessions should send five copies of a 75-word abstract to Society headquarters, 216 West 102nd Street, New York 25, N. Y., and a single copy of the abstract to F. W. Koerker, Chairman, Industrial Electrolytic Division, The Dow Chemical Company, Midland, Mich., or notify the Vice-Chairman of the Division, A. R. Orban, Niagara Alkali Company, Niagara Falls, N. Y., as soon as possible and certainly no later than January 15, 1954.

SECTION NEWS

Niagara Falls Section

The 1953–54 season of the Niagara Falls Section began September 9th at the Youngstown Yacht Club with an informal "mixer" meeting. The members and guests spent an enjoyable evening which included speed boat rides,

C. C. Furnas

refreshments, a buffet supper, and an informal talk, "Trends in Modern Aircraft," by Dr. C. C. Furnas, Director of the Cornell Aeronautical Laboratory.

Dr. Furnas briefly reviewed the very rapid development of aircraft from the first flight, half a century ago, to the present status of a weapon carrier which, in the time of war, can make possible total global war. Dr. Furnas then described the trends in aviation for the next fifty years, predicting future changes in fuels, propulsion systems, speeds, helicopters, and commercial aircraft. The future of commercial aviation is very promising indeed, with an estimated air travel of the order of 100 billion passenger miles being predicted by the year 2000. The meeting was closed with a discussion of guided missiles and rockets.

J. E. Currey, *Secretary*

India Section

Symposium on Electrolytic Alkali-Chlorine

This symposium was given by the India Section during February 195 and the papers presented there have been published in the *Bulletin of the India Section of The Electrochemical Society*, Volume 2, No. 3, 1953 (Jun Journal, page 166*C*).

* * *

Symposium on Non-Ferrous Metal Industry

The National Metallurgical Laboratory, Jamshedpur, has arranged for a Symposium on "Non-ferrous Metal Industry in India" in January 1954. The topics for discussion cover extraction and refining, melting and foundry technique, thermal treatment and fabrication technique, powder metallurgy, protective coatings, expansion of the industry, economics.

T. L. Rama Char

International Council for Electrodeposition

The International Council is making plans for the International Conference of 1954 to be held in London, April 21 to 24. Participation by overseas delegates is anticipated, including a strong contingent of scientists and technicians from the States. The Council hopes to organize a special session to discuss the latest American practice in electrodeposition.

William Blum To Be Honored

Dr. William Blum has been invited by the Council of the Institute of Metal Finishing to give the Hothersall Memorial Lecture for 1953–54 on the eve of the International Conference. This lecture will be under the auspices of the I.M.F. Dr. Blum is well-known for his numerous researches in the field of electrodeposition covering many years of active study of electrochemical processes and problems.

Aims of the Council

At its first, recent meeting, the International Council considered such questions as the mutual interchange of publications between countries, and further concluded that such questions as universal standards of electroplating and universally-agreed nomenclature and definitions of terms used in electrodeposition should be explored and would well repay future study.

Fifth Dinner of Chemical Profession in Cleveland

The fifth annual dinner of The Chemical Profession in Cleveland will be held at the Hollenden Hotel on November 11. Professor Harold C. Urey, of the Institute of Nuclear Studies, University of Chicago, will speak on "Cosmic Chemical Engineering." The dinner is sponsored jointly by the Cleveland sections of the American Chemical Society, Alpha Chi Sigma, American Institute of Chemists, The Electrochemical Society, and The American Institute of Chemical Engineers.

Conference on Luminesence

The Electronics Group of the Institute of Physics is organizing a conference on luminescence, with particular reference to solid inorganic phosphors, to be held in Cambridge, England, from April 7 to 10, 1954. Communications regarding the meeting should be sent to Dr. S. T. Henderson, The Institute of Physics, 47, Belgrave Square, London, S.W. 1, England.

PERSONALS

James H. Moore has been named general manager of Vacuum Metal Corporation, Cambridge, Mass. Mr. Moore was previously with the National Research Corporation in Cambridge.

Hugh V. Alessandroni has been promoted from manager of research to assistant technical director, National Lead Company, Titanium Division, Perth Amboy, N. J.

Thomas Hazen, Bakelite Company, Division of Union Carbon & Carbide Corporation, Bloomfield, N. J., is now located at the Bakelite plant in Bound Brook, N. J.

Morris Feinleib, Division of Metallurgical Research, Kaiser Aluminum & Chemical Corporation, Spokane, Wash., has transferred to the Permanente Research Laboratory at Permanente, Calif.

A. F. Garcia, Kaiser Aluminum & Chemical Corporation, Chalmette, La., has been transferred to the company's Oakland, Calif., office.

Milo W. Krejci, formerly of Reconstruction Finance Corporation, Tin Division, Washington, D. C., is now engaged in consulting metallurgical work. After December 1 he will be located in Newark, Del.

Christian Aall, Development Director, Phosphate Division, Monsanto Chemical Company, is now at the company's St. Louis, Mo., office. Dr. Aall had been at Anniston, Ala.

Russell H. Axsom, Michigan Chrome & Chemical Company, Detroit, has been appointed Vice-President of the Company. He was general manager.

H. A. Cataldi, formerly with the Standard Oil Company in Chicago, is now with the General Electric Company in Schenectady, N. Y.

Joseph L. Collins has opened an office as consulting engineer in the Statler Building, Boston, Mass. Mr. Collins was previously connected with Aerovox Corporation, New Bedford, Mass.

Norman H. Kirk, Works Manager, Park Bros., Ltd., Blackburn, Lancs, England, has joined the Bankfield Works in Blackburn, England.

Robert A. Oler of Solvay Process Division, Allied Chemical & Dye Corporation, Syracuse, N. Y., has transferred to the company's plant at Moundsville, W. Va.

Clarence G. Ozar of Cowles Chemical Company has been transferred from Cleveland, Ohio, to Syracuse, N. Y.

Carlton M. Dean, Monsanto Chemical Company, St. Louis, Mo., has been named manager of the engineering sales department of the company's Organic Chemical Division. Mr. Dean has been associated with Monsanto since 1917.

Thomas M. Rodgers, Hanson-Van Winkle-Munning Company, Matawan, N. J., was appointed sales representative for the territory south of Wilmington, with headquarters in Baltimore. Mr. Rodgers previously served the company in eastern Pennsylvania.

S. Krishnamurthi, chemist at the Indian Telephone Industries, Ltd., Bangalore, India, has been elected an Associate of the Royal Institute of Chemistry, London.

NEW MEMBERS

In September 1953, the following were elected to membership in The Electrochemical Society:

Active Members

James H. Battle, National Lead Research Labs., 105 York St., Brooklyn, N. Y. (Corrosion)

Charles R. Brummett, Acheson Plant, National Carbon Co., Niagara Falls, N. Y. (Industrial Electrolytic)

Arthur A. Cline, Great Lakes Carbon Corp., mailing add: Rt. 2, Box 19-D, Morganton, N. C. (Electrothermic)

Stanley M. Davis, American Cyanamid Co., Calco Chemical Division, Bound Brook, N. J. (Electro-Organic and Theoretical Electrochemistry)

Philip B. Dettmer, Cobalt Chemicals Ltd., Cobalt, Ont., Canada (Electrothermic and Industrial Electrolytic)

Robert L. Dillon, General Electric Co., mailing add: 623 Cottonwood, Richland, Wash. (Corrosion)

John L. Everhart, Materials & Methods, 330 W. 42 St., New York, N. Y. (Corrosion and Electrodeposition)

Daniel R. Frankl, Sylvania Electric Products Inc., Physics Labs., Bayside, N. Y. (Electronics)

James F. Hunt, Great Lakes Carbon Corp., mailing add: 200 Park St., Morganton, N. C. (Industrial Electrolytic)

Hillard J. Jendrzynski, General Motors Corp., Research Lab. Div., 485 W. Milwaukee, Detroit, Mich. (Electrodeposition and Theoretical Electrochemistry)

Myer Krulfeld, Metallurgy Div., Naval Research Laboratory, Washington, D. C. (Corrosion, Electrodeposition, and Theoretical Electrochemistry)

Malcolm McLoud, United States Rubber Co., 1230 Sixth Ave., New York, N. Y. (Battery and Electric Insulation)

Arthur E. Middleton, Battelle Memorial Institute, Columbus, Ohio (Electronics)

James L. Miller, National Carbon Co., mailing add: 8465 Usher Rd., Olmsted Falls, Ohio (Corrosion and Industrial Electrolytic)

John W. Pearce, S. C. Johnson & Son, mailing add: 5106 Wind Point Rd., Racine, Wis. (Electro-Organic)

John J. Stokes, Jr., Aluminum Co. of America, mailing add: Station St.,

Box 212, Unity, Pa. (Battery and Industrial Electrolytic)

Reinstatement

EDWIN M. SHERWOOD, Battelle Memorial Institute, Columbus, Ohio (Electrothermic)

Associate Members

KEITH G. BLANTON, Naval Ordnance Laboratory, mailing add: 1444 Kanawha St., Apt. 101, Hyattsville, Md. (Battery)

NORMAN C. CRAIG, Harvard University, mailing add: 6513 Barnaby St., Washington, D. C. (Theoretical Electrochemistry)

VAUGHN S. HARRIS, Owens-Corning Fiberglas Corp., Research & Dev. Labs., Newark, Ohio (Battery)

SUNDARESA SOUNDARARAJAN, General Chemistry Dept., Indian Institute of Science, Bangalore, India (Electro-Organic)

Student Associate Members

MYRON O. DAVIES, Western Reserve University, mailing add: 13436 Harlan Ave., Lakewood, Ohio (Battery and Theoretical Electrochemistry)

ROBERT C. GRIFFIS, Western Reserve University, mailing add: 25340 Lakeshore Blvd., Euclid, Ohio (Electrodeposition and Theoretical Electrochemistry)

ROBERT S. JOHNSON, Dept. of Chemistry, Ohio State University, Columbus, Ohio (Electro-Organic)

ROBERT W. PENN, Western Reserve University, mailing add: 2060 Cornell, Cleveland, Ohio (Electrodeposition and Theoretical Electrochemistry)

FRANK L. SAUNDERS, Western Reserve University, mailing add: 9805 Manor Ave., Cleveland, Ohio (Theoretical Electrochemistry)

ROMEO R. WITHERSPOON, Western Reserve University, mailing add: 11215 Wade Park Ave., Cleveland, Ohio (Battery)

LETTER TO THE EDITOR

Iron Passivation in Nitric Acid

Dear Sir:

S. Aronow, in his letter on this subject in the April issue of your JOURNAL, called attention to the effect of a current pulse on passive films. The undersigned, when working with W. H. J. Vernon at the Chemical Research Laboratory, Teddington, England, devised a passivity test for low alloy steels which might well be improved by the use of impulsive current.

A particular difficulty of accelerated corrosion tests of the intermittent spray type seemed to be that of correctly placing in an order of merit those steels (e.g., the chromium bearing steels) which depend for their resistance upon an inherent tendency to passivity. It was found that such steels became passive in different strengths of nitric acid and the behavior of a steel in a critical concentration of acid enabled a correction to be applied which was successful in bringing the results into line with those found on normal atmospheric exposure.

The steel, after the nitric acid dip, was plunged into sodium carbonate solution. Timing and temperature were very critical and the test was some what "messy." The use of impulsive currents might result in a far more elegant test.

JOHN A. LEWIS
Widnes, Lancashire,
England

BOOK REVIEWS

APPLIED INORGANIC ANALYSIS (2nd ed.) by W. F. Hillebrand and G. E. F. Lundell; second edition revised by G. E. F. Lundell, H. A. Bright, and J. I. Hoffman, 1034 pages. John Wiley & Sons, Inc., New York, and Chapman Hall, Limited, London, $15.00.

Those of us to whom Applied Inorganic Analysis is an indispensible reference text are, I am sure, profoundly grateful to have this revision of Hillebrand and Lundell's monumental work. It is doubtful whether any other published text has been as valuable to the practicing analytical chemist in the past two decades as has this one. Its value lies in the fact that it is a critical summation of the important methods of analysis of metals rather than a comprehensive, noncritical accumulation of methods. The authors have "separated the wheat from the straw," as it were, and in doing so have performed an invaluable service for their fellow analysts.

In the present revision, the basic value and the elegance of presentation of the 1929 edition have been preserved. At the same time, the text has been altered to include new knowledge, t amplify certain chapters dealing wit subjects that are of great topical i terest, and to correct typographic errors. No attempt has been made t describe in detail the new techniques analytical chemistry such as polarog raphy, chromatography, flame photom etry, mass spectrometry, etc., for thi is not a book of special techniques, bu one devoted primarily to separation and reactions that are fundamental t analytical chemistry.

The chapters on niobium an tantalum, tin, and the platinum metal have been entirely rewritten to bring them up to date, but because of space limitations no attempt has been made to expand the chapter on uranium in proportion to the new material made available in the last decade.

The portion of the 1929 book on Silicate and Carbonate Rock Analysis has been retained fundamentally unchanged, but the part that dealt with the Analysis of Soda-Lime Glass, Bauxite, and Refractories has been omitted to permit the introduction of new material throughout the book without increasing it to an unwieldly size.

The book is well bound and printed in "easy to read" type. Altogether this is a very welcome addition to the analyst's library.

C. L. LUKE

TEXTBOOK OF QUANTITATIVE INORGANIC ANALYSIS, 3rd Ed., by I. M. Kolthoff and E. B. Sandell. The Macmillan Company, New York, 1952. xv plus 759 pages, $6.50.

The third edition has been expanded somewhat. The authors have added the Bronsted theory of acid and bases, a discussion of separation by coprecipitation, and brief description of some physical methods, namely, flame photometry, fluorescence and radioactivity measurements, mass spectrometry, Raman spectrography, and x-ray diffraction and absorption.

The sections on organic reagents, chromatography, and spectroscopy have been expanded, and the sections on indeterminate errors and colorimetry and spectroscopy revised. In some chapters problems have been added or changed. One procedure from the revised edition has been omitted and a procedure for fluorine in rocks added.

The format has been changed to provide a better appearance. This new format is noticeably harder to read. The lines are longer and the type is larger than in the revised edition.

The book remains a very useful reference book for instructors and students. It is doubtful whether many freshman chemistry courses enable students to use this book as a text in their second year.

PAUL D. GARN

RECENT PATENTS

Selected for electrochemists by Fred W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

June 23, 1953

Cox, G. C., 2,643,222, Method of Cathodically Descaling and Electrode Therefor

Notvest, R. W., 2,643,223, Apparatus for Electrolytic Analysis

Niccoli, P., 2,643,224, Ozonizers

Jones, H. F., and Colby, H. R., 2,643,225, Electroplating Rack

Salauze, J., 2,643,276, Negative Electrode for Alkaline Storage Batteries and Method of Manufacturing the Same

Falkenthal, E. E., 2,643,277, Photovoltaic Cell

Simpson, A. W., 2,643,278, Dry Cell

Bradley, J. C., 2,643,279, Separator Protector

June 30, 1953

Fischer, J., 2,643,959, Process for the Protective Treatment of Iron

Neish, R. A., 2,643,975, Method of Lead Coating a Ferrous Article

Hamister, V. C., 2,644,020, Graphization of Carbon Articles

Moulton, J. D., Schweitzer, E. F., and Briggs, T. R., 2,644,022, Alkaline Storage Battery with Negative Iron Electrode

Rasch, C. H., 2,644,023, Storage Battery Paste With Amino Dye as Ion Exchange Expander

Schumacher, E. A., and Heise, G. W., 2,644,024, Anode Assembly for Primary Galvanic Cell

Dunham, L. R. S., 2,644,025, Air-Depolarized Primary Cell

July 7, 1953

Bonn, T. H., and Wendell, D. C., Jr. 2,644,787, Electrodeposition of a Magnetic Coating

Shenk, W. J., Jr., 2,644,788, Electrodeposition of Nickel

Shenk, W. J., Jr., 2,644,789, Electrodeposition of Nickel
Tapke, K. W., 2,644,851, Thermocouple
Dunlap, W. C., Jr., 2,644,852, Germanium Photocell

July 14, 1953

Herres, S. A., and Redden, T. K. 2,645,575, Chromium-Nickel Titanium Base Alloys
Madorsky, S. L., and Brewer, A. K., 2,645,610, Process for the Separation of Isotopic Ions
Axtell, W. G., 2,645,611, Method of and Bath for Electrolytic Polishing
Taylor, R. D., 2,645,612, Sacrificial Anode
Walton, H. F., 2,645,635, Method of Regenerating Electrolytic Polishing Solutions
Arvin, M. J., 2,645,675, Thermoelectric Generator and Method for Production of Same
Emériat, R., 2,645,676, Method of Assembling and Insulating Flat Dry Cells
Morin, F. J., 2,645,700, Semiconductor of Mixed Nickel Manganese and Iron Oxides
Kerridge, F. E., Belham, M., and Pearce, G., 2,645,701, Electrical Resistor and Resistance Elements Therefor

July 21, 1953

Dean, R. S., 2,646,396, Method of Making Electroformed Articles
Wean, R. J., 2,646,397, Electroplating Zinc Using Titanium Containing Electrolyte
Henderson, H. P., 2,646,398, Electroprocessing Apparatus
Herold, V., 2,646,454, Process for the Manufacture of Battery Electrodes and the Resulting Electrodes
Jeannin, R. A. A., 2,646,455, Electrolytic Cell and Battery
Jacquier, P. A. C., 2,646,456, Fabrication of Storage Battery Plates
Jacquier, P. A. C., 2,646,457, Electrode for Alkaline Batteries
Walz, H. P. H., 2,646,458, Galvanic Cell
Gill, W. L., 2,646,459, Electric Storage Battery Venting System

July 28, 1953

Homer, H. H., 2,647,066, Phosphor Suspension and Method of Applying
Williams, P. D., 2,647,067, Electron Emitter for Electron Tubes
Burnham, J., 2,647,079, Production of Insulated Condenser Electrodes
Joyce, R. M., 2,647,080, Light-Stabilized Photopolymerization of Acrylic Esters
Doering, W. v E., and Knox, L. H., 2,647,081, Photochemical Preparation of Tropilidenes
Kent, D. W., 2,647,082 Electrolytic Cells of the Tank Type
Homer, H. H., 2,647,086 Methods of Phosphor Manufacture
Fortney, D. F., 2,647,087 Improved Calcium Fluorophosphate Phosphor Containing Aluminum
Guerry, W. R., 2,647,153 Protector Skid for Thermocouples
Rupp, J. L., Dickover, M. W., Willihnganz, E., and Snyder, A. H., 2,647,154, Storage Battery
Dyer, C. A., 2,647,155, Primary Electrolytic Cell or Group of Cells
Booth, F., 2,647,157, Electrical Storage Battery
Booth, F., 2,647,158, Method of Making Acid Resisting Microporous Material for Storage Battery Separators
Lighton, L. E., 2,647,159, Storage Battery Filling and Venting Structure
Brown, B. B., 2,647,216, Dispenser Cathode
Foulke, T. E., 2,647,217, Electric Discharge Lamp

RESEARCH TEAM NEEDED

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Chemical engineers	

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Require CHEMIST qualified as STENOGRAPHER. 70% analytical work, 30% of time in library research, record keeping, correspondence, purchasing, and invoicing. State experience and salary required. *Reply to Box A-250.*

Ludvika, A. A., 2,647,226, Dry Rectifier Valve Plate

Lacey, W. M., 2,647,227, Dry-Plate Rectifier

August 4, 1953

Cook, N. E., and Norteman, S. L., 2,647,304, Process of Terne Coating Metal and Terne Coated Product

Cook, N. E., and Norteman, S. L., 2,647,305, Process of Tight Coat Hot Dip Galvanizing and Hot Dip Galvanized Product

Perl, M. L., and Elliott, J. R., 2,647,841, Preparation of Luminescent Screens

Goffredo, D. L., 2,647,864, Etching Process

Freud, H. M., 2,647,865, Brightening Aluminum and Aluminum Alloy Surfaces

Brown, H., 2,647,866, Electroplating of Nickel

Schaltegger, H., 2,647,867, Process for Production of Cholesteryl Esters Brominated in Position 7

Dean, F., 2,647,868, Color Removal from Esters

LITERATURE FROM INDUSTRY

High Vacuum Pumps. Two Kinney midget vacuum pumps are described and illustrated in a 4-page bulletin, featuring high pumping speed; low absolute pressures to 0.2 micron; small, standard motors; rugged construction; quiet operation; no discharge oil vapor; automatic lubrication: compact, entirely self-contained; light weight, easily portable. Model CVM 3153, smallest pump in the Kinney line, is specially designed for laboratory projects, industrial installations, refrigeration service applications, and wherever a very compact pump of high pumping speed is required. Widely used alone or as a fore pump for small diffusion pumps. Efficient mechanical seal prevents oil seepage at the main drive shaft and excludes atmospheric air. Model CVM 3534 has high pumping speed and dependability designed for small industrial applications, and research and processing operations. Minimum attention required. Double rotary shaft seal with independent oil reservoir prevents atmospheric air leakage into the pump. Kinney Manufacturing Co. P-157

Soniclean Process. A special technical folder illustrates and describes the new Detrex Soniclean Process, the application of ultrasonic energy for the cleaning of metal parts. It can be applied to nonabsorbent materials such as metals, glassware, and molded products; removes iron oxide residues to a degree previously not obtainable; and quickly removes soils from cavities, shallow indentations, small holes, interiors of hypodermic needles, and other precision finished surfaces. Detrex Corp. P-158

Thermocouple Tables. New reference tables for iron-constantan thermocouples, covering a very broad range—from −310° to +1600°F—constitute an important step toward uniformity in this field. Recommended by the Scientific Apparatus Makers of America for adoption as a tentative standard. National Bureau of Standards. P-159

Rubber Tubing Chart. A rubber tubing wall chart has been designed for maximum convenience and instant reference for use in storerooms and laboratories. Includes 18 actual-size illustrations of amber and black tubing, giving inside and outside dimensions, physical properties, and prices. Arthur S. La Pine & Co. P-160

Guide of Testing Instruments. A new 16-page buyer's guide provides data on such instruments as hook-on volt-ammeters, hook-on wattmeters, hook-on power-factor meters, portable recorders, voltmeters and ammeters, phase-sequence indicators, hand pyrometers, surface roughness scales, insulation-resistance meters, and others. Includes application data, features of each instrument, and prices. General Electric Co. P-161

Thermal Conductivity Units. Illustrated bulletin is available on Gow-Mac thermal conductivity cells. Contains information on specifications, applications, sampling, accuracy, repairs, etc. Gow-Mac Instrument Co. P-162

Simplified Recording Potentiometer. A new booklet fully illustrates and describes all features of the simplified Weston Recording Potentiometer, which is of completely new design with all parts interchangeable, with a universal slide wire that never needs changing, and which permits chart speeds to be changed on-the-line by a simple screwdriver adjustment. Weston Electrical Instrumental Corp. P-163

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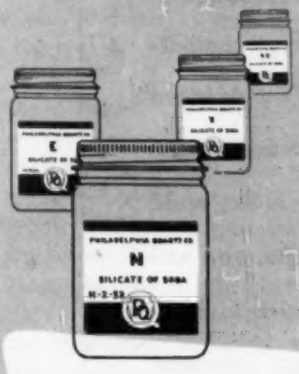

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TV Picture Tube Components. Tungsten and chemical components for television picture tubes are described in a 4-page booklet. Also described are screen phosphors, potassium silicate for screen settling, tungsten wire for cathode heaters, triple carbonate cathode coatings, stranded tungsten coils, and filaments for vacuum metallizing. Sylvania Electric Products Inc. P-164

Acid-Proof Coatings. New bulletin covers DURO-KOTE acid-proof coatings. These materials give the highest type of vinyl and butadiene styrene acid-proof resin protection against acids, alkalies, and many solvent actions. Planned primarily as acid-proof and alkali-proof maintenance paints useful in metal finishing, chemical, synthetic fiber, textile dye house, tannery, coal mine, metallurgical and electrometallurgical, and food plants. Electro Chemical Engineering & Mfg. Co. P-165

Dial Thermometers. A new 16-page, illustrated bulletin describes dial thermometers for long distance measurement. It emphasizes the variety of ranges, and the bulbs, tubing, and accessories available, and provides complete data on temperature indicators of the vapor pressure and gas pressure types. The Foxboro Co. P-166

To receive further information on any New Product or Literature from Industry listed here, send inquiry, with key number, to Journal of The Electrochemical Society, 216 West 102nd Street, New York 25, N. Y.

Please print your name and address plainly.

NEW PRODUCTS

Mass Spectrometer. A new mass spectrometer designed to meet process instrumentation requirements in the gas, petroleum, pharmaceutical, and chemical fields has been announced. The new instrument uses the principle of ion resonance. In addition, a sample inlet system allows direct connection to a stream or process line, thus permitting continuous sample introduction. General Electric Co. N-28

CRC Diode Tester. A rugged, precision instrument for testing both dynamic and static characteristics of crystal diodes has been developed. The new CRC Diode Tester (Model 136) tests both forward and back characteristics, indicating how the diode will perform before mounting it in the circuit. Can also be used for periodic circuit checks to detect potential diode failures before they occur. Is adaptable to high speed, volume testing, and operates on 115-volt, 60-cycle current, using 100 watts or less. Computer Research Corp. N-29

New Temperature Limited Diodes. Two new tubes have been added to the line of "Kalotron" diodes. These diodes have temperature limited emission characteristics where the anode current is a direct function of filament voltage. Due to the use of a pure tungsten filament, the specified ratings are maintained throughout the normal life of the tube. Thermosen, Inc. N-30

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Philadelphia Quartz Company 323C

Rapid Electric Company . . 294C

E. H. Sargent & Company . 290C

ELECTROCHEMIST

Major electrochemical producer needs experienced man to plan and carry out fundamental studies in the field of fused salt electrolysis. Should have three to five years experience in devising experimental equipment plus some experience in high temperature measurements—preferably with fused salts. Should have good theoretical background in physical chemistry including solid state physics, theory of solutions, and experience in electrical measurements. Preferably should have Ph.D. Salary commensurate with ability and experience. Southern location. *Reply to Box A-251.*

EMPLOYMENT SITUATION

Please address replies to box shown, c/o The Electrochemical Society, Inc., 216 W. 102nd St., New York 25, N. Y.

Position Wanted

Chemist, 34, family, seeks research work or managerial position in control, in Atlantic coastal region; has 10 years experience including storage batteries, electroplating (barrel and still), gelatines, glues, varied physical and chemical commercial testing, and laboratory and materials manufacture responsibilities in nylon throwing. *Reply to Box 353.*

Technical Review

On the Electrochemistry of Ion-Exchange Resins

A Review of Recent Work

K. S. Spiegler[1]

ABSTRACT

Electrochemical properties of ion-exchange resins such as specific conductances, ionic mobilities in the resins, and potentials across resinous membranes have been measured recently. A review of these measurements and their correlation to the general thermodynamic treatment of ion-exchange resins is presented. Applications such as the use of resinous membranes as ionic sieves, electrolytic regeneration of ion-exchange resins, and the use of ion-exchange resins as media for electrophoretic separations are discussed.

Introduction

Synthetic ion-exchange resins have been known for about 15 years and, apart from their use in a great variety of applications, several points of theoretical interest such as adsorption isotherms and exchange kinetics have been investigated. While the electrochemical properties of natural ion-exchange materials and different synthetic materials of low capacity had been investigated previously, the study of the electrochemistry of the synthetic resins and the correlation of the data to the resin equilibria have developed only during the last few years. These studies are reviewed here. Ionic migration in the resins proper is discussed first, followed by the electrochemistry of systems containing both resins and solutions.

The methods used so far in these studies are very similar to those used in previous researches dealing with other materials. Thus, ion-exchange membrane potentials have been measured by standard methods as applied previously to collodion-base membranes, and the conductance of ion-exchange resins was determined in cells like those used for aqueous solutions. To interpret their results, investigators have drawn extensively on well-known theories such as Kohlrausch-Weber's equations of electromigration and the Gibbs-Donnan theory of membrane equilibria. However, as the exchange-resins are solid in the gross physical sense and yet act in almost all other respects like solutions of electrolytes, the results are of a particular nature and point to interesting future applications.

The results of these investigations confirmed the structural model of ion-exchange resins (1, 2). They are solid polyelectrolytes consisting of a hydrocarbon crosslinked skeleton to which polar groups are attached. Thus the motion of one charge type of ion is restricted. In nuclear sulfonic cation-exchange resins, such as Dowex-50, the bound groups are the $-SO_3^-$ anions. The counter-ions, in this case cations, may be considered dissociated from this skeleton—similar to the dissociation of an ionized salt in concentrated solution. Because of electrostatic attraction, the small cations remain in the vicinity of the polyanion and can move into water or a solution only to the extent determined by the relation between their thermal energy to electrostatic attraction. They can, however, move freely inside the resin. In other words, the resin may be visualized as an anionic sponge filled with cations, the latter being replaceable by a mechanism similar to musical chairs (3).

If an electrical field is applied to a cation-exchange resin, one would expect the mobile cations to migrate in the direction of the current, while the anions are immobile, since they are bound to the hydrocarbon skeleton. Similarly, in an anion-exchange resin, the current should be carried by the mobile anions. This conclusion is indeed borne out by experiments.

Conductance of Exchange Resins

Measurements of the specific conductance of resin plugs were made by packing the wet, granular materials between electrodes connected to a Wheatstone bridge (4–6a). The conductance depends somewhat on the pressure applied to the plug, but at light pressures, just sufficient to insure good contact, conductance readings are reproducible within a few per cent. Conductance measurements in resinous membranes reproduce better. These measurements are made by clamping the wet membrane, which is protected from moisture loss, between the electrodes of a conductance cell (7–9).

Dry exchange resins are very poor conductors. With increasing moisture content, the specific conductance increases abruptly (4). The conductance of commercial granular resins, which have a high capacity, is predominantly ionic; conductances of granular Dowex-50 measured with direct current are almost identical with those measured at 60 and 100 cycles alternating current (6). In resins of low exchange-capacity, the ionic contribution is less, and hence the impedance depends appreciably on the frequency of the applied potential. Albrink and Fuoss (10) analyzed the a-c electrical properties of an anion-exchange membrane of low capacity and calculated a-c and d-c components. The d-c conductance of the membrane changed with the electrolytic environment, but the a-c properties were substantially unaffected. The conductance of a phenolsulfonic acid formaldehyde polymer was found to increase appreciably with the frequency of the applied potential (10a).

Heymann and O'Donnell (5) measured the specific conductances of a phenolsulfonic resin (Amberlite IR-100) in different forms. The resin was placed in conductivity water.

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A representative set of their results is listed in Table I, which shows the equivalent conductance $\Lambda = k/c_R$, c_R representing the capacity of the resin (in equivalents of exchangeable hydrogen per ml cell space), and k the specific conductance of the resin plugs (in mho cm^{-1}), which is an average conductance of swollen resin plus free water. These values are compared to the equivalent ionic conductance, l_c^∞, at infinite dilution for an aqueous solution at 18°C.

TABLE I. *Conductance of Amberlite IR-100 in different forms at 18°C* (5)*

Resin particle size: 0.2–1.0 mm; plug: 1.35 cm diam, 4.0 cm length; cell constant = 2.79; c_R = 0.764 meq/ml column space or 2.9 meq/gram gel water

Ion	Resistance, R (ohm)	Eq. conductance, Λ (mho cm^2 eq^{-1})	Ionic conductance in water (infin. dil.), l_c^∞	$\frac{l_c^\infty}{\Lambda}$	Ionic conductance in 2.9 molal nitrate solution, l_c	$\frac{l_c}{\Lambda}$
H^+	200 ± 5	18.3	313.9	17.2	(191)†	(10.4)
Li^+	2505 ± 10	1.46	33.3	22.8		
Na^+	1849 ± 5	1.98	43.4	22.0	(19.5)	(9.9)
K^+	1375 ± 5	2.66	64.6	24.3	(32.3)	(10.2)
NH_4^+	1153 ± 5	3.17	64.7	20.4		
Ag^+	8600 ± 100	0.42	54.0	130	(26.4)	(63.8)
Mg^{++}	7000 ± 100	0.52	45.9	90		
Ca^{++}	7300 ± 100	0.50	51.9	100	(16.5)	(33)
Ba^{++}	12700 ± 200	0.29	55.4	190		
La^{3+}	45000	0.07	61.0	900		
Th^{4+}	74000	0.05	23.5	1000		

* Reproduced in part by permission of the *Journal of Colloid Science*.

† Values in brackets are calculated from available data (13) by interpolation and extrapolation.

TABLE II. *Conductance of Dowex-50 in different forms at 27.5°C* (6)*

Resin particle size: 80–100 mesh (dry basis); plug: 1.6 cm diam, length 10 cm; c_R = 1.96 meq/ml column space or 5.3 meq/gram gel water

Ion	Specific conductance k (mho cm^{-1})	Eq. conductance, Λ (mho cm^2 eq^{-1})	Ionic conductance of cation in an aqueous chloride solution, 5.3 molal (18°C) l_c'	l_c'/Λ
H^+	10.0×10^{-3}	5.1	(135)	(26.4)
Na^+	1.22×10^{-3}	0.62	(14)	(22.6)
Zn^{++}	0.60×10^{-3}	0.306	(7.5)	(24.5)

* Values in brackets are calculated from available data (13) by interpolation and extrapolation.

Table II shows some conductance measurements with Dowex-50 (6) and in Table III the specific conductances of some ion-exchange membranes are listed for comparison (8, 11, 12).

It is seen that the conductances can be classed in four groups; the hydrogen resin having the highest conductance, followed by the alkali metal resins, whose conductances are comparable and increase with the atomic weight as in aqueous solution, the silver and alkaline earth resins whose conductances are considerably lower, and, finally, the lanthanum and thorium resins, which are very poor conductors.

Heymann and O'Donnell (5) compared the equivalent conductance, Λ, of the resin to the ionic conductance, l_c^∞, of the same ion in an aqueous solution at infinite dilution. Their values for the ratio l_c^∞/Λ are listed in Table I. It is seen that this ratio is about equal for the alkali metal and hydrogen ions, and increases with the valency of the ion. By comparing the equivalent conductance of a resin to the ionic conductance l_c, of the same ion in a comparable aqueous solution of the same molality as the resin, one can obtain an idea about the strength of binding of the ions in the resin. For if all resin salts were completely dissociated and the presence of the crosslinked matrix acted merely as a viscous factor, increasing the frictional resistance of the medium on the moving particles, the migration of all types of cations would be slowed down to the same extent, and the ratio l_c/Λ would be equal for all cations. If the resin were a labyrinth of fine pores, similar to a sponge, the ratio l_c/Λ would represent a measure for the tortuosity of the path of the ions, similar to the formation factor used in soil science (14). It will be shown later, however, that some properties of the resin can be explained more adequately by a one-phase, solid electrolyte model.

TABLE III. *Specific conductance of ion-exchange membranes in various forms*

Membrane	Type	Mobile ion	Temp (°C)	Specific conductance, $k \times 10^3$ (mho cm^{-1})	Reference
Nepton CR-51*	Homogeneous phenolsulfonic cation-exchanger	Na^+	23	7.8	(11)
		Zn^{++}	27	3.7	(11)
		Ca^{++}	27	4.4	(11)
Nepton ARX-44*	Homogeneous moderately basic anion-exchanger	Cl^-	25	9.0	(8)
Amberplex C-1†	Nonhomogeneous sulfonic acid cation-exchanger	Na^+	25	0.48	(12)
		H^+	25	3.6	(12)
Amberplex A-1†	Nonhomogeneous strongly basic anion-exchanger	Cl^-	25	0.46	(12)
		OH^-	25	1.1	(12)
		SO_4^{--}	25	0.34	(12)

* Product of Ionics, Inc., 152 Sixth St., Cambridge, Massachusetts. The "Nepton" resin membranes were previously called "Permionic."

† Product of Rohm and Haas Company, Washington Square, Philadelphia, Pennsylvania.

Since it is found that the ratio l_c/Λ varies with the types of ions considered, one may conclude that the higher this ratio, the less the dissociation of the respective resin salt. It would be logical to compare the resins to the corresponding monomeric solutions, for instance, sodium Dowex-50 to a solution of sodium toluyl sulfonate of equal molality. Since sufficient conductance data on such solutions are not available, the resin forms in Tables I and II have been compared to nitrate and chloride solutions, respectively. It is seen that the general trend of the ratios l_c/Λ for Amberlite IR-100 confirms the qualitative conclusions drawn from the ratios l_c^∞/Λ, indicating that the strength of binding increases with the valency of the cation. The monovalent silver ion is seen to be bound considerably stronger than the alkali metal ions.

The data for Dowex-50 are not sufficiently extensive to allow definite conclusions. In this case, the value of the ratio l_c'/Λ is almost the same for the three ions tabulated, suggesting that the dissociation of the hydrogen, sodium, and zinc

ems of Dowex-50, which contains no phenolic groups, is out equal.

These considerations have a direct bearing on the question electrophoretic separations in the resin phase. For if the sinous polyanion shows specific interaction with certain tions, this effect may increase differences in the mobility two ions and make their separation easier. It must, how- er, be borne in mind that the methods used in the measure- ent of the conductance of resin plugs are rather crude and, erefore, the conclusions drawn from them must be con- dered merely qualitative. As soon as precision measurements conductances of resins become available, a more satisfying rrelation between binding strength and conductance should possible.

Correlation of Self-Diffusion Coefficients in Resins to the Electrical Conductance

Self-diffusion in the resins is invariably smaller than for the me ions in water, and decreases with increasing ionic charge 15).

From the measured conductance of an ion-exchange mem- ane, it is possible to calculate the self-diffusion coefficient an ion, D, (cm^2 sec^{-1}) in the resin by means of the Nernst-Einstein formula (16), which in the case of ion-exchange resins sumes a particularly simple form, since the current is car- ed only by one charge type of ion (11, 16).

$$D = kTm/Z\mathbf{F} = 2.66 \times 10^{-7}\ \Lambda/Z \text{ at } 25°C$$

here R is the gas constant (watt sec deg^{-1} $mole^{-1}$), T the bsolute temperature, $\mathbf{F}$ Faraday's constant (coul eq^{-1}), Z he valency of the ion, m its electrical mobility (cm^2 $volt^{-1}$ ec^{-1}), and Λ the equivalent conductance of the resin (mho m^2 eq^{-1}).

These values can be compared to those obtained from the bserved spread of radiotracers on ion-exchange membranes 11) and to those computed from the rate of isotopic exchange etween a resin and a solution (16, 17). A comparison of these alues is shown in Table IV.

It is seen that the agreement is fairly good except for cal- ium, and the data show that the mechanisms of diffusion and lectrical conductance in the resin are similar. All the values omputed from the electrical conductance are higher than hose obtained from the radioactive tracer method. This iscrepancy is believed to be due to electroosmosis, and is iscussed in a later section.

Both specific conductance (18) and self-diffusion rates 15, 19) diminish considerably with increasing crosslinking f the resin matrix, and it may be possible to develop an nalytical method for the determination of the degree of cross- inking based on conductivity measurements.

So far, it has been assumed that the transference number of he mobile ions in a resin salt, with respect to the macro- olecular immobile matrix, is unity. This assumption was roved by the study of electromigration in the resins analogous o the moving boundary method used in solutions and also y the measurement of potentials in systems containing ion- xchange resins. These experiments have a number of further mplications and are discussed in the following paragraphs.

Electromigration in Ion-Exchange Resins

When current flows through an ion-exchange resin, elec- rode reactions occur and often cause chemical changes in the esin. However, one can use electrode materials which do not ause uch changes. For instance, if the zinc form of Dowex-50 s ele trolyzed between zinc electrodes, an amount of zinc ions equivalent to that which is removed from the resin at the cathode is supplied at the anode by the reaction:

$$2R^- + Zn = ZnR_2 + 2e^- \qquad (I)$$

(where R represents one gram-equivalent of resin anion) and the resin remains in the zinc form.

Electromigration in this system was studied by the "moving boundary method," tagging a thin lamina of the resin column with 250d Zn^{65}, observing its progression by means of radioactive counting equipment, and correlating it to the total amount of charge passed (6). If the very small differences between the ionic mobilities of the zinc isotopes are neglected, the rate of progression of the lamina, dz/dt, should equal the ratio between the flux of cations, n_c, and the concentration:

$$\frac{dz}{dt} = \frac{n_c}{c_R} = \frac{T_c i}{\mathbf{F} c_R}$$

where z is the length coordinate in the direction of the current, t the time, c_R the capacity of the resin (meq/ml column space), T_c the transference number of the cation with respect to the resin matrix, i the current density (ma cm^{-2}), and $\mathbf{F}$ is Faraday's constant (coul. eq^{-1}).

TABLE IV. *Self-diffusion coefficients, D, in phenolsulfonic ion-exchange resins as determined by different methods* (11)

Cation	Resin	Temp, °C	Self-diffusion coefficient, $D \times 10^6$ cm^2 sec^{-1}		
			Kinetic	Radioactive tracer spread	Electrical conductance
Sodium	Amberlite IR-1	30	2.1		
	Nepton CR-51	23		1.95 ± 0.25	2.15 ± 0.20
Zinc	Nepton CR-51	27		0.41 ± 0.05	0.48 ± 0.05
Calcium	Nepton CR-51	27		0.31 ± 0.05	0.58 ± 0.05

T_c was found to be unity, and this result was confirmed by measuring the progression of a traced zinc lamina at the zinc-sodium boundary of the system:

$$\oplus \quad Zn \mid ZnR_2 \mid NaR \mid Zn \quad \ominus$$

If sodium Dowex-50 is electrolyzed between platinum electrodes, the following electrode reactions occur (5, 20):

Anode: $$4R^- + 2H_2O = 4HR + O_2(g) + 4e^- \qquad (II)$$

Cathode: $$4e^- + 4NaR + 4H_2O = 4R^- + 4Na^+ + 2H_2(g). \qquad (III)$$

Reaction (II) produces continuously the hydrogen form of the resin, and hence the resin can be regenerated by electrolysis without the use of acid solutions. The current yield decreases, however, as electrolysis proceeds, for the hydrogen ions formed at the anode penetrate the whole sodium layer, eventually reaching the cathode, when the following reaction competes with reaction (III):

$$4e^- + 4HR = 4R^- + 2H_2(g). \qquad (IV)$$

Hence, the current yield (as eq. HR formed per faraday) decreases as soon as this reaction starts. Analogous phenomena were observed in anion-exchange resins. In this case, hydroxyl ions are formed at the platinum cathode. The mobility of iodine was measured by a radiotracer method, and the progress of the hydroxyl ions measured by the use of phenolphthalein indicator (9).

It was found that if a sharp boundary exists initially between two forms of the resin, such that the slower cation is

behind the faster with respect to the direction of the current, the boundary remains sharp during electromigration. In the reverse case, mixing occurs. This is analogous to the behavior of boundaries in aqueous solutions. By virtue of reaction (II), the anode is equivalent to an initial $HR \mid NaR$ boundary.

Spiegler and Coryell (6) applied Weber's electromigration equations (21), and presented a simplified treatment of this phenomenon, treating the resin as a homogeneous medium. They neglected diffusion, as in their experiments the electrical force on the ions caused by the applied potential was much larger than the osmotic force causing diffusion.

From the general equations, derived under the assumption that the ratio of the mobilities of the adsorbed ions is independent of the composition of the resin, one can calculate the distribution of hydrogen and sodium ions at any point and at any time during the electrolytic regeneration process of the sodium resin, described by equations (II) and (III).

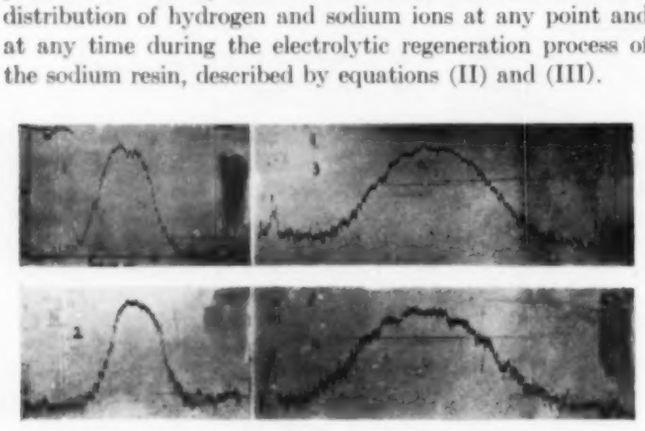


FIG. 1. Comparison of densitographs of autoradiographs of a Nepton CR-51 membrane (product of Ionics, Inc., Cambridge, Mass.) in the sodium form containing a lamina traced with $2.6y$ Na^{22}. Sections 1 and 2 represent the initial activity distribution in the two halves of the membrane, respectively; sections 3 and 4 show the distribution after 8 hr, section 3 in the upper half, which was left in distilled water, and section 4 in the lower half, which was electrolyzed. Autoradiographic exposure: sections 1 and 2, 5 min; sections 3 and 4, 12 min; all on Kodak Medical X-ray Film (No-Screen). Total migration of peak in section 4: 4.9 cm.

After an electrolysis period of t seconds, the following three regions are found in the resin: (a) a zone adjacent to the anode which contains only HR:

$$z < it/\mathbf{F}c_R M,$$

where z is the distance from the anode (cm), i the current density (ma cm^{-2}), t the time (sec), $\mathbf{F}$ Faraday's constant (coul. eq^{-1}), c_R the resin capacity (meq ml^{-1}), and M the mobility ratio m_{H^+}/m_{Na^+}; (b) a mixed zone containing both HR and NaR:

$$it/\mathbf{F}c_R M < z < itM/\mathbf{F}c_R,$$

in which the concentration of HR equals

$$c_{HR} = \frac{1}{M-1}\left[(itc_R M/\mathbf{F}z)^{\frac{1}{2}} - c_R\right]$$

The length of this mixed zone increases linearly with time; and (c) a zone adjacent to the cathode containing only NaR:

$$z > itM/\mathbf{F}c_R$$

Thus an approximate picture of the efficiency of the electrolytic regeneration process can be obtained.

While no direct determination of the concentrations along the column was made, the theory was applied to the progression of a traced lamina of the sodium resin. As electrolysis proceeds, the rate of progress of the activity maximum de creases and the band spreads, owing to penetration of hy drogen ions into it. Comparison of the observed rate of migra tion of the activity maximum to the calculated values showe that the progress is faster than predicted under the assump tion of independent ionic mobilities.

In the electrolysis of the sodium form of carboxylic ex change resins, such as Amberlite IRC-50, a sharp boundary between the anodic hydrogen form of the resin and the sodium form is maintained during electrolysis, as the net mobility of hydrogen ions in these resins is lower than of the sodium ions. This case is analogous to the boundary acetic acid | so dium acetate in aqueous solution which remains very sharp during electromigration (22). However, hydrolysis of the resin salt is appreciable, and the specific resistance of the hydrogen form of the resin is very high because the degree of dissociation of the carboxylic groups is low.

Separations by Electromigration in Ion-Exchange Resins

The use of solid media for electromigration separations has found increasing attention in recent years (23). Filter paper (24, 25), silica jelly (26), and agar gel (27) have been used, and ion-exchange resins, in particular in the form of membranes, may now be added to this list. While the ac curate optical methods of analysis used in aqueous solutions cannot be applied to them, they offer other advantages such as stoichiometric ion-binding, low diffusion rates, the possi bility of direct cooling by flowing water, and, as in other solid media, the absence of convection.

In principle, two methods of separation seem possible. In the first, which is used extensively for electrophoretic separations in solutions (28), a small amount of the mixture to be separated is placed in a large excess of "supporting electrolyte." The function of the latter is to keep the potential gradient constant and thus prevent "boundary anomalies."

Electromigration under such conditions is illustrated by the experiment described in Fig. 1. A thin lamina of a cation-exchange membrane ("Nepton CR-51," product of Ionics, Inc., Cambridge, Massachusetts) in the sodium form was traced by adsorbing a small amount of $2.6y Na^{22}$ and the membrane electrolyzed between zinc electrodes. The activity of the traced lamina was determined by autoradiography. The optical density of the autoradiographs was subsequently recorded by a recording densitometer. The activity distribution in the electrolyzed half of the membrane is compared to a blank kept in distilled water for an equal period of time. It is seen that both bands spread by diffusion and their shape is almost the same.

Were the resin membrane material proper not homogeneous,[2] the spread of the migrating band would be larger. Thus the difference between the diffusion spread and the spread associated with electromigration is considerably larger in columns of granular resin particles than in resinous membranes.

If two kinds of ions of different mobility are absorbed, the peaks will migrate at different rates and separation can be achieved.

In the second method of separation, the mixture is placed between layers of other electrolytes such that the ions of lower mobility migrate behind those of higher mobility. Thus, to separate sodium from potassium, the mixture is adsorbed on a lamina of an ion-exchange membrane such that it is sand-

[2] The membranes are backed by a Lumite screen, the effects of which can be seen in the densitograph. The screen represents the only inhomogeneity of the system.

riched between an anodic section of ZnR_2 and a cathodic section of HR, and a current is passed through the membrane using zinc electrodes. In the experiment described in Fig. 2, the sodium had been traced with $2.6y Na^{22}$. As the band progressed, the boundaries remained sharp, and partial separation of sodium from potassium occurred. The discontinuities of the curves are due to the presence of the Lumite screen backing material.

A similar technique had been used previously by Kendall (29) in electroseparations in agar gel. He was able to separate ions of very similar properties such as the rare earths, but did not succeed in separating isotopes. Because of their mechanical stability, ion-exchange resins offer possibilities which were absent in the soft gels.

For instance, such separations can be carried out on a rotating wheel (30). The ions to be separated are adsorbed on a thin section of a resin membrane belt mounted on a wheel, and, while they migrate, the wheel rotates in the opposite direction with a speed equal to the average of the speeds of the ions to be separated. The principle of this arrangement is similar to the "squirrel wheel." It represents an infinite path length for electromigration separations and, since the electrodes are applied in the vicinity of the boundaries of the

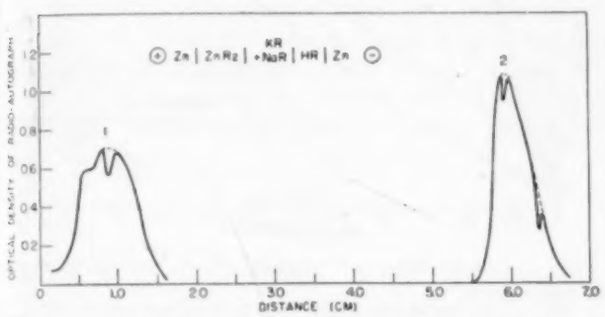


FIG. 2. Partial separation of sodium and potassium by electromigration in a Nepton CR-51 membrane. Sodium traced with $2.6y$ Na^{22}. Figure shows densitographs of membrane radioautographs.

region of the ions to be separated, only a minimum of electric power is dissipated in the remainder of the membrane.

The wheel is shown in Fig. 3. A mixture of alkali ions is absorbed in the top section of the resin belt which rests on the wheel.[3] The anode consists of cadmium amalgam (5% cadmium) held in a cell whose bottom is made of 66-gauge Nylon hose, and makes electrical contact with the resin belt. The cathode is a platinum sheet. At the start, the position of the zones is represented by the following scheme:

$$\oplus \quad \text{Cd} \mid \text{Na}R + \text{K}R \mid \text{H}R \mid \text{Pt} \quad \ominus$$
$$+ \text{Cs}R$$

As the current flows, cadmium "dissolves" in the resin by a reaction similar to (I):

$$\oplus \quad \text{Cd} \mid \text{Cd}R_2 \mid \text{Na}R + \text{K}R \mid \text{H}R \mid \text{Pt} \quad \ominus$$
$$+ \text{Cs}R$$

This increases the resistance between the electrodes, since HR conducts better than CdR_2. The current is kept constant by an electronic current regulator, and hence the voltage increases. This voltage signal is fed back into an electronic motor controller accelerating a motor which, through a gear train, turns the wheel from right to left until the alkali ion band is about in the middle between the electrodes. Henceforth the feedback mechanism controls the position of the alkali ion band at this spot during the passage of the current.

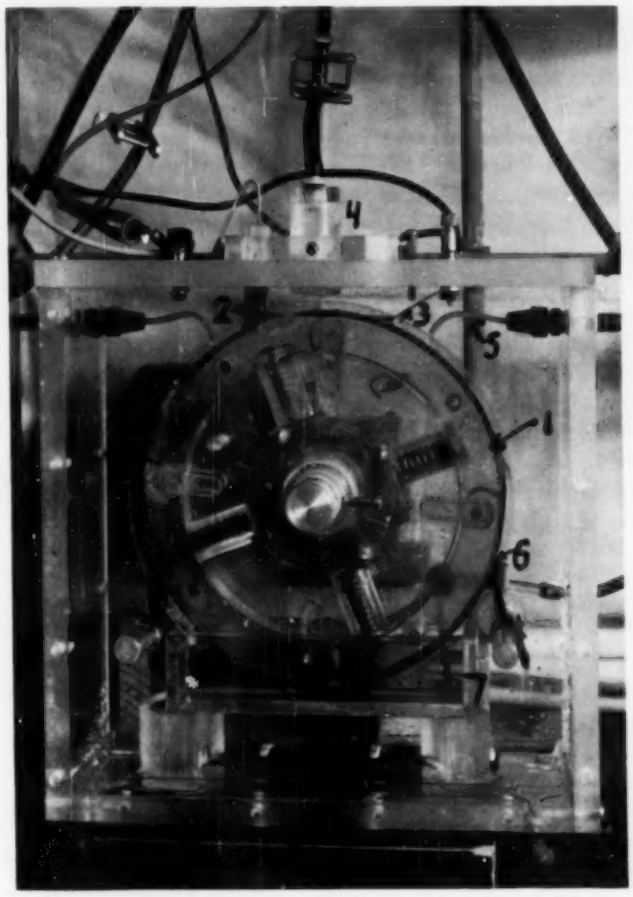


FIG. 3. Apparatus for ion separation on a rotating ion-exchange membrane belt. Figure shows the circular membrane belt [1] held on a Lucite wheel under spring tension, liquid cadmium amalgam anode [2], platinum cathode [3], rinsing system consisting of a shower head [4], side sprinklers [5], and water deflectors [6]. The acid regenerating vessel [7] is seen at the bottom. Wheel diameter: 7 in.

When separation is complete, the zones are represented as follows:

$$\oplus \quad \text{Cd} \mid \text{Cd}R_2 \mid \text{Na}R \mid \text{K}R \mid \text{Cs}R \mid \text{H}R \mid \text{Pt} \quad \ominus$$

Successful separations of alkali metal ions by this method have been reported (30), but, for the time being, this work is still in a development stage.

Such separations are also possible in beds of granular resins (6, 31, 32). For instance, partial separation of cupric from cobaltous ions, both adsorbed on Amberlite IRC-50, was observed when the column was electrolyzed (31). In this case, the progress of the separation could be observed visually, as the resin is white and both cations colored.

Diffusion of Electrolytes into the Resin

The solid polyelectrolyte model of ion-exchange resins also proved very useful in the interpretation of potential measurements which provided further insight into ion-exchange resins, in particular systems containing both resins and solutions, as compared to the work discussed in the previous paragraphs which dealt mainly with ion-exchange resins in a medium of pure water.

[3] The author is greatly indebted to Dr. A. A. Kasper of Ionics, Inc., for the belts of "Nepton CR-51" resin. These belts contained no backing material.

In the theoretical interpretation of these data, account has to be taken of the penetration of electrolytes from the solution into the resin. When the resins are in equilibrium with solutions of electrolytes, they are no longer ideal cation or anion conductors, respectively.

Diffusion of electrolytes into resins had been observed in industrial ion-exchange practice and numerous data compiled on the need for "leaching" resin columns long before fundamental studies of this effect were undertaken.

Were the ion-exchange particle an inert, rigid sponge without surface activity, the amount of solution taken up by it would be independent of the concentration. From this viewpoint, there is more or less void space in the resin and this is occupied by solution of essentially the same composition as externally. Thus, in the case of Dowex-50, there would be two "types" of sodium ion in the resin phase, namely, at the exchange site position and in the interstitial solution (33). One would expect that the ratio, r, between the concentration of an electrolyte inside the resin (in meq ml^{-1}) to the concentration of the same electrolyte in solution would be constant and equal to the fractional pore volume of the resin. The same effect would result from the presence of cracks in the resin particles.

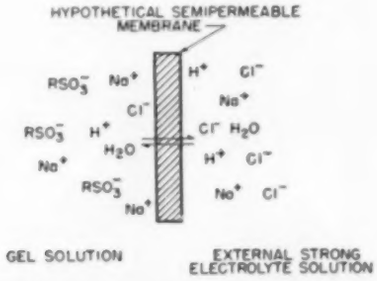


FIG. 4. Schematic representation of electrolyte partition between a strong acid cation exchanger and an external aqueous phase. (Reproduced by permission of *Annual Reviews, Inc.*, Stanford, Calif.) (2)

Experiments show that as the concentration of the electrolyte increases, r increases, and the resin shrinks. These phenomena cannot be accounted for satisfactorily by the two-phase sponge model. They can be explained (34–36) by extending to ion-exchange resins the theory of membrane equilibria developed by Gibbs (37) and Donnan (38).

In the Gibbs-Donnan model, the ion-exchanger particle may be regarded as a macromolecule acting as its own membrane. It is permeable to the ions found in the solution, but impermeable to the fixed ionic groups bound to its lattice. Thermodynamically, it can be treated as a concentrated solution. This situation is illustrated in Fig. 4 for sodium Dowex-50 in equilibrium with a solution of sodium chloride. As soon as electrolyte is taken up, the sodium ions that enter the resin phase from the solution, together with the chloride ions and the sodium ions which had been previously in the resin and held in stoichiometric proportion to the fixed anionic groups, are no longer treated as different from each other.

Conductivity measurements of resinous membranes are in better agreement with the Donnan than with the sponge model. Data on conductivity and equilibrium distribution of NaCl for "Nepton CR-51" cation-exchange membrane have been reported by Juda and coworkers (7, 39). They equilibrated a sulfonic acid cation-exchange membrane in the sodium form with a solution of sodium chloride, determined the conductance of the resin, and also separated the membrane from the solution and determined by analysis the amount of sodium chloride that had diffused into the resin. One can calculate the specific conductance: (*a*) assuming that the resin does not interact with the pore solution (two phase concept; sponge with straight, wide pores); (*b*) assuming that the electromigration of the sodium and chloride ions is subject to the same "viscous" resistance in the resin (characterized by the ratio l_c/A) as is the sodium ion in the pure sodium form of the resin in the absence of chloride (one phase Donnan concept). As shown in Fig. 5, it is then found that values calculated under assumption (*a*) are much higher than under (*b*). The experimental values (39) are near to the values calculated under assumption (*b*), but a little higher which may be due to the presence of a small amount of the external solution in cracks or adhering to the resin surface. Therefore it seems reasonable to consider this particular resin as a one-phase system with a small correction for two-phase behavior.

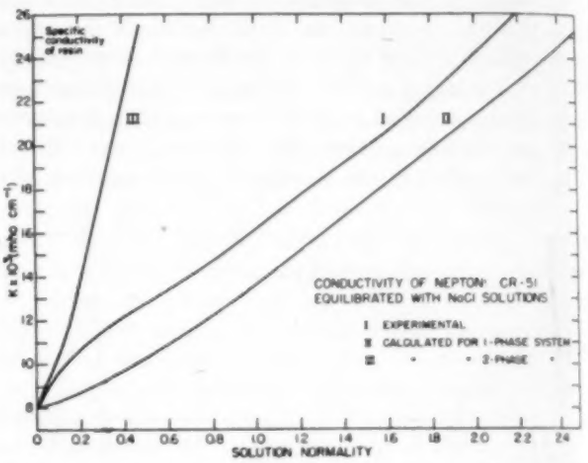

Specific conductivity of resin
CONDUCTIVITY OF NEPTON CR-51 EQUILIBRATED WITH NaCl SOLUTIONS
I EXPERIMENTAL
II CALCULATED FOR 1-PHASE SYSTEM
III " " 2-PHASE "
SOLUTION NORMALITY

FIG. 5. Conductivity of Nepton CR-51 equilibrated with NaCl solutions.

It might be conjectured that the approximate agreement of the experimental data with those computed by method (*b*) is no proof for the Donnan model, for even for the sponge model one would expect lower conductivities than calculated under assumption (*a*) because of the lower value of the mobility in the capillaries than in a free solution. For instance, in a certain type of wet filter paper, the mobility of albumin was found to be approximately 30 per cent less than in water (24). This reduction, however, is far too small to account for the low values of the observed resin conductivities, and hence, if capillaries exist, they must be extremely narrow. Possibly their cross section is of molecular dimensions. In this case, the resin can no longer be treated as a two-phase system, and its properties must be expected to approach those of the one-phase model. A similar viewpoint has been applied recently by Schmid to the interpretation of the electrical properties of collodion membranes (40). Recent electron micrographs of different ion-exchange materials (40a) show that the pore size in synthetic resins is indeed very small. The pore diameter of a synthetic cation-exchange resin was found to be of the order of 10 Å units, whereas in an inorganic synthetic ion-exchange gel it was several orders of magnitude larger. It is, therefore, not surprising that significant differences in electrolyte distribution characteristics were found in the study of different ion-exchange materials.

Gibbs-Donnan Model of Ion-Exchange Resins

The quantitative treatment of the one-phase "Donnan" model of the resin follows closely along the exact thermodynamics of membrane equilibria developed by Donnan and Guggenheim (41), and only some of its most fundamental

tures are briefly outlined in the following. The model is chematically represented in Fig. 4, showing the resin and olution phases separated by an imaginary membrane which s impermeable to the sulfonic groups. Phase equilibrium etween two electrolyte solutions in the same solvent and f unequal concentration is possible if there is a differnce in the pressure to which the phases are subjected. The omponents inside the resin particle are assumed to be subected to the pressure of the strained hydrocarbon network f the solid polyelectrolyte while no such pressure acts in the olution.

Gibbs has shown (37) that if a system of this kind is in quilibrium, the temperature is constant and the chemical otentials, μ, of any component that can pass through the embrane are equal in the two phases:

$$\mu^s(p^s, T) = \mu^r(p^r, T)$$

here p is the pressure, T the absolute temperature, and he superscripts, s and r, refer to solution and resin phase, espectively.

The activity, a, of a component is defined by the equation,

$$\mu = \mu^0(p, T) + RT \ln a$$

here $\mu^0(p, T)$ is the standard chemical potential of this omponent. We chose the same standard state of the comonent in the solution and resin phase, namely, at unit pressure and at the prevailing temperature, T. The variation of he chemical potential with pressure is given by the well-known relation,

$$\left(\frac{\delta\mu}{\delta p}\right)_T = \bar{v} \qquad (V)$$

here $\bar{v}$ is the partial molar volume of the component. Substituting these relations in the Gibbs equation we obtain

$$\mu^0(1, T) + \int_1^{p^s} \bar{v}dp + RT \ln a^s = \mu^0(1, T) + \int_1^{p^r} \bar{v}dp + RT \ln a^r.$$

If the compressibility of the component is considered negligible, i.e., its partial molar volume is independent of the pressure, this equation reduces to

$$\ln \frac{a^s}{a^r} = \bar{v}(p^r - p^s)/RT = \bar{v}\pi/RT \qquad (VI)$$

where π, termed the swelling pressure, is defined as the difference between the pressure in the resin and the solution which is in equilibrium with it.

Equation (VI) is valid for each component of the system that can pass through the membrane. Combining two equations for the electrolytes MX and NX, respectively, and using the definition of the activities of the ions,

$$(a_{M^+})(a_{X^-}) = a_{MX}; \qquad (a_{N^+})(a_{X^-}) = a_{NX}$$

one obtains

$$\ln \frac{(a^r_{M^+})(a^r_{N^+})}{(a^s_{M^+})(a^s_{N^+})} = \ln \frac{(m^s_{M^+})(m^r_{N^+})}{(m^r_{M^+})(m^s_{N^+})} \frac{(\gamma^s_{M^+})(\gamma^r_{N^+})}{(\gamma^r_{M^+})(\gamma^s_{N^+})} = \frac{\pi(\bar{v}_{M^+} - \bar{v}_{N^+})}{RT} \equiv K \qquad (VII)$$

where a stands for the ionic activities, m the molalities, and γ the ionic activity coefficients of the ions. K is a real constant only to the extent that the swelling pressure is independent of the ion activities. There is no way to measure the individual ionic activity coefficients without further assumptions.

To test equations (VI) and (VII) one has to know the activity coefficients of the components in the resin and in the solution and the swelling pressure, π. The activity coefficients in the solution are often known, but the activity coefficients in the resin have to be estimated.

To determine the swelling pressure, π, in sulfonic acid resins, Glueckauf (42) compared the partial pressure of water vapor of these resins to the partial vapor pressure of water of a very slightly crosslinked resin of equal molality. (These two resins are not in thermodynamic equilibrium.) As the water molecules in the highly and the weakly crosslinked resin are in similar media except for the different pressure prevailing in these resins, the observed difference of the partial vapor pressure of water is attributed to this pressure difference. From these data, pressure differences of the order of several tens to several hundreds of atmospheres were computed, depending on the volume of the resin and on the degree of crosslinkage. If the resin of low crosslinkage is considered essentially strainless, the computed pressure difference between the two resins represents the pressure prevailing in the highly crosslinked resin particles. The volume of the resin was found to decrease linearly with increasing pressure.

The importance of the swelling pressure term in equations (VI) and (VII) has been discussed by Gregor (36) and a theory developed which is based on the linear relationship between swelling pressure and resin volume. This term is very important in the interpretation of swelling phenomena of the resin. However, if one wants to predict from equations (VI) and (VII), respectively, the amount of electrolyte in the resin in equilibrium with the solution, or the exchange equilibrium constant for two ions, one has to estimate the activity coefficients of the ions in the resin, and the uncertainty involved in the estimation of the logarithm of this factor is often of the same order of magnitude or larger than the whole swelling pressure term (19, 34). Since there is no exact theory by which the activity coefficients in such concentrated systems as ion-exchange resins can be estimated, activity coefficients in aqueous solutions of 1–1 electrolytes of equal ionic strength have been used or empirical rules applied.

Thus measuring the uptake of KCl by anion-exchange membranes and neglecting the swelling term on the right side of equation (VI), Manecke and Bonhoeffer (9) reported fair agreement between the measured values and the values calculated under the assumption that the mean ionic activity coefficients of KCl in the resin are equal to those of aqueous solutions of KCl of equal ionic strength.

Several investigators (34, 43, 44) used Harned's rule (45) for the estimation of mean ionic activity coefficients in the resin. This rule had proved of great value in the estimation of activity coefficients in mixed concentrated aqueous solutions from activity coefficients in the solutions of their components. A detailed discussion of these researches is outside the scope of this paper, but a few further remarks on the application of the Donnan theory to the diffusion of electrolytes into the resin will be made.

Applying equation (VI) to the equilibrium between a solution of a chloride, MCl, and a cation-exchange resin in the M form, MR, one can again split the activity of MCl into the ionic activities and obtains:

$$\ln \frac{(a^s_{M^+})(a^s_{Cl^-})}{(a^r_{M^+})(a^r_{Cl^-})} = \ln \frac{(m^s_{MCl})^2(\gamma^s_{\pm})^2}{(m^r_{M^+})(m^r_{Cl^-})(\gamma^r_{\pm})^2} = \pi\bar{v}_{MCl}/RT \qquad (VIII)$$

where $(\gamma\pm)^s$ and $(\gamma\pm)^r$ are the mean ionic activity coefficients of MCl in the solution and the resin, respectively.

The distribution of MCl between the resin and the solution is not equal, and considering that the right hand term of equation (VIII) is positive, it is seen that the presence of a considerable concentration of mobile M^+ ions in the exchanger causes the activity and the concentration of the chloride ion in the exchanger to be smaller than in the solution.

Thus, electrolytes are partially excluded from the resin, while the equilibrium distribution of nonelectrolytes of low molecular weight between resin and solution is roughly equal on a molality basis. This ion exclusion principle has been used to separate electrolytes from nonelectrolytes (46). To test equation (VIII), Boyd and Larson (34) determined by neutron activation analysis the diffusion of HCl, LiCl, and HBr into nuclear sulfonic cation exchangers of the sulfonated polystyrene-divinylbenzene copolymer type. Their results for HCl, illustrating the strong dependence of the phenomenon on the degree of crosslinking, are shown in Fig. 6. The

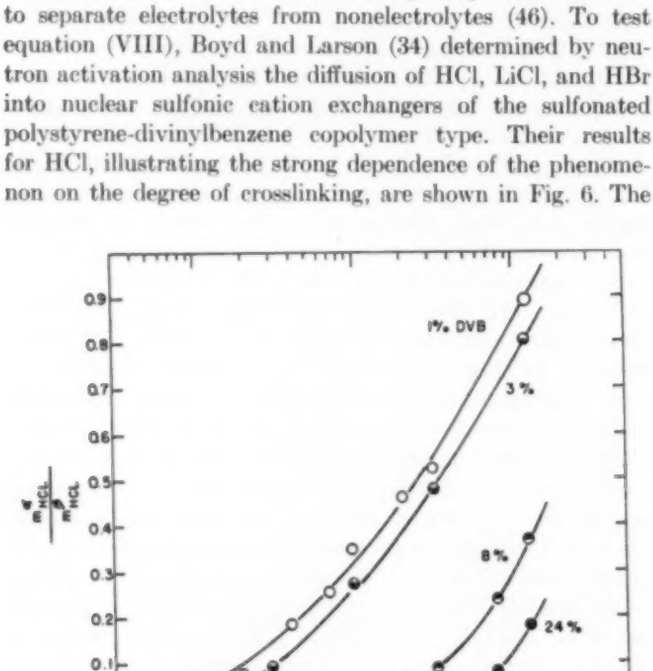


FIG. 6. Variation of distribution of diffusible chloride ion in polystyrene DVB copolymers with external concentration and crosslinking. Electrolyte: HCl (Reproduced by permission of Dr. G. E. Boyd.)

degree of crosslinking is indicated by the nominal divinylbenzene (DVB) content of the resin. The ratio of the molalities of HCl, m^a/m^s, in the resin and solution phases is plotted against the logarithm of the molality. Analyzing these curves and estimating π at roughly 100 atm, they reached the conclusion that the osmotic free energy term in equation (VIII) is small compared to the logarithm of the activity coefficient of HCl in the resin. In other words, ionic interaction plays a more important part than the osmotic free energy in determining diffusion of these electrolytes into the resin.

Equation (VIII) leads to the postulate that the values of m^a/m^s should approach zero at infinite dilution when plotted against log m^s as in Fig. 5. It is seen that this is indeed the case. In previous studies (1, 7, 8) of this and other types of resins, similar results were obtained, but the values of m^a/m^s approached a constant low value, but not zero, at low values of m^s. These findings may have been due in part to incomplete phase separation or to small cracks and channels in the resin particles. They were reported for both cation and anion-exchange (46a) resins, and lead to abnormally low activity coefficients, $\gamma_\pm$, in resins in equilibrium with solutions of low concentration. They provide an indication that the resins are not quite ideal homogeneous single-phase systems and that some allowance must be made for two-phase behavior.

Potential Measurements Across Synthetic Ion-Exchange Membranes

The connection between the ion-exchange properties of a membrane material and its permselectivity, i.e., its ability to transfer only certain kinds of ions, in particular positive or negative ions, had been known even before synthetic ion-exchange resins became available and was treated quantitatively by Teorell (47, 48) and by Meyer and Sievers (49, 49a). This subject is of considerable interest in the biological sciences because of the permselective properties of many biological membranes.

If a solid is able to exchange ions readily with a solution and this ability extends to layers beneath the solid surface this evidently proves that the exchanging ions can migrate freely in the solid. Consequently, when a membrane made of an ion-exchange material is placed between two solutions and a potential is applied, exchangeable ions are transferred from one solution to the other. Nonexchangeable ions can pass through the membrane only to the extent that they can enter the membrane by a mechanism different from ion exchange. For instance, if the membrane has comparatively wide channels which can fill with solution, nonexchangeable ions can pass through these channels from one side of the membrane to the other. Synthetic membranes made of ion-exchange resins have, in general, no wide pores. In equilibrium with dilute solutions the resins were shown to take up only very small amounts of electrolytes.

If a cation-exchange membrane is placed between dilute solutions and an electrical potential applied across it, the current is carried primarily by the cations, because the anions from the solution are almost completely excluded from the resin and the fixed anion groups of the resin are immobile. Thus, in dilute solutions, cation-exchange membranes are almost impermeable to anions, acting as "ionic sieves" which screen out the anions. Similarly, anion-exchange membranes are impermeable to cations.

As the concentration of the solutions increases, electrolytes from the solutions are taken up by the membrane. Both cations and anions participate now in the transport of current across the membrane and hence its permselectivity decreases with increasing electrolyte concentrations.

To obtain fundamental data on resin behavior in such systems, electrical potentials were measured across two reference electrodes in contact with solutions of different concentrations which are separated by an ion-exchange membrane. These measurements represent a continuation of extensive previous researches on permselective membranes of biological origin, of clay (50) and collodion which were recently reviewed by Sollner (51). The main advantages of the synthetic resinous membranes are their low specific resistance, high capacity, and mechanical stability, which may lead to industrial applications where other materials failed.

Consider a cell consisting of silver-silver chloride electrodes in aqueous solutions of KCl of activities a_1^{KCl} and a_2^{KCl}, respectively, separated by a membrane. Neglect the transport of water associated with the transfer of ions. If the membrane is ideally permselective and transfers only potassium ions, the reversible passage of one Faraday involves the transfer of one mole of KCl from one solution to the other. As the

reversible electrical work equals the difference of the chemical potentials of KCl in the two solutions, we obtain:

$$E = \frac{RT}{F} \ln \frac{a_1^{KCl}}{a_2^{KCl}} = \frac{RT}{F} \ln \frac{a_1^{K^+}}{a_2^{K^+}} + \frac{RT}{F} \ln \frac{a_1^{Cl^-}}{a_2^{Cl^-}} = E_{K^+} + E_{Cl^-} \qquad (IX)$$

where E is the measured potential, $\mathbf{F}$ Faraday's constant, R the gas constant, T the absolute temperature, and a^{K^+} and a^{Cl^-} are the ionic activities of potassium and chloride ions, respectively. The ionic activities cannot be measured separately. The measured potential can be considered split into two parts, E_{Cl^-} and E_{K^+}, the first of which is attributed to the sum of the electrode potentials and the second to the membrane. In the following reasoning in this section the ionic activities of the potassium and chloride ions will be set equal to each other, since this is convenient, and since, from a thermodynamic viewpoint, the magnitude of the measured potentials, e.g., E, of a complete cell does not depend on the manner in which the potential difference is distributed within the cell. The potentials E_{K^+} and E_{Cl^-} are then equal. They will be designated as E_0. When this treatment is extended to solutions other than potassium chloride, this assumption must be kept in mind.

If calomel electrodes are used instead of silver-silver chloride electrodes, and if the sum of the liquid junction potentials between them and the potassium chloride solutions is negligible, the potential difference between the calomel electrodes equals E_0, the membrane potential of the ideally permselective membrane:

$$E_0 = \frac{RT}{2F} \ln \frac{a_1^{KCl}}{a_2^{KCl}} = \frac{RT}{F} \ln \frac{c_1(\gamma_{K^+})_1}{c_2(\gamma_{K^+})_2} \qquad (X)$$

where γ_{K^+} is the ionic activity coefficient of potassium, which was set equal to the mean activity coefficient of potassium chloride.

In general, the membranes are not ideally permselective and only a fraction $\bar{T}_{K^+}$ of the current is carried by the potassium ions. Hence the potential between the silver-silver chloride electrodes equals:

$$E = (\bar{T}_{K^+}) \frac{RT}{F} \ln \frac{a_1^{KCl}}{a_2^{KCl}} = 2(\bar{T}_{K^+})E_0 = E_M + E_0 \qquad (XI)$$

where E_M is the membrane potential of the non-ideal membrane and hence:

$$\bar{T}_{K^+} = \frac{E_M}{2E_0} + 0.5.$$

Thus the average transference number, $\bar{T}_{K^+}$, of the potassium ions in the membrane, as defined by equation (XI), can be determined from the measurement of the potential E, provided the activities of the electrolyte in the solutions are known. The average transference number is the quantitative measure for the permselectivity of the membrane under the given conditions.

In general, it is found that the transference number of the exchangeable ion equals unity at low concentrations of the solutions and decreases with increasing solution concentration. This fact is due to the diffusion of electrolyte into the resin which causes a certain proportion of the current to be carried by the nonexchangeable ions.

If the Donnan concept is applied to the ion-exchange material as discussed in the previous section, and if the concentrations are so small that the activity coefficients are unity, the membrane potential can be predicted from the capacity of the resin c_R, the concentrations of the electrolytic solutions on the two sides of the membrane, c_1 and c_2, respectively, and the ratio of the mobilities m_+ and m_- of the two ions in the membrane. Neglecting the osmotic pressure terms in the membrane equilibrium equations, the following expression for the membrane potential was obtained in the case of a 1-1 electrolyte (47, 49):

$$E_M = \frac{RT}{2F} \ln \frac{x_2 + c_R}{x_2 - c_R} - \frac{RT}{2F} \ln \frac{x_1 + c_R}{x_1 - c_R} + \frac{RT}{F} U \ln \frac{x_1 + Uc_R}{x_2 + Uc_R} \qquad (XII)$$

where

$$x_1 \equiv \sqrt{c_R^2 + 4c_1^2}, \quad x_2 \equiv \sqrt{c_R^2 + 4c_2^2}, \quad \text{and } U \equiv \frac{m_+ - m_-}{m_+ + m_-}$$

Usually the mean ionic activity coefficients of the electrolyte $(\gamma_\pm)^r$ and $(\gamma_\pm)^s$ in the resin and solution, respectively, cannot be assumed to equal unity, and equation (XII) has to be modified by substituting $c_R(\gamma_\pm)^r$ for c_R, and $c(\gamma_\pm)^s$ for c (9, 52). This is done under the simplifying assumption that $(\gamma_\pm)^r$ is constant throughout the membrane. An alternative derivation, based on the general flow equations in electrolytic systems, has been discussed by Schloegl (53, 54), and by Lange and Schuecker (54a).

The three terms in the expression for the membrane potential [equation (XII)] can be considered as the two "Donnan" potentials at the interfaces between the membrane and the solutions and the diffusion potential within the membrane. Combining equations (XI) and (XII), it is seen that the permselectivity of the membrane should decrease with increasing solution concentration and increase with increasing capacity, c_R, of the ion-exchange material. It is the latter property that makes the synthetic ion-exchange resins of high capacity particularly suitable as permselective materials. Hence considerable effort has been spent to prepare ion-exchange resins in the shape of membranes and to measure potentials across them.

Potential measurements across ion-exchange resins have been carried out in solutions of KCl, NaCl, LiCl, and HCl, using membranes made completely of ion-exchange materials (9, 39, 52, 55–61) and membranes containing ion-exchange resins and inert resinous binders (12, 62, 62a).

The main result of all these researches is that in dilute solutions the average transference number of the cations approaches, indeed, unity within a few per cent. Some results for the inhomogeneous membranes of Wyllie and Patnode are shown in Table V (62).

It is seen that, in dilute solutions of HCl, the response of the membranes to hydrogen ions is very similar to that of a glass electrode.

The measurement of potentials across membrane electrodes can be used to determine activities of sodium and other ions by the use of a modified form of equation (X) by methods analogous to the pH measurement with a glass electrode. As for the concentration range in which equation (X) is claimed to be valid, considerable differences are found in the literature for different types of membranes. Kressman (56) reported a linear relationship between membrane potentials and the logarithm of the ratio of the activities of the alkali metal ions up to activities of 2.0, and Wyllie and Patnode (62) state that the agreement between the mean potentials given by some of their membranes and the potential computed under the assumption of unit transference number for the cation

may be considered reasonably satisfactory in the case of 3.000*M* and 0.462*M* NaCl solutions, and fair in the case of 4.000*M* and 0.700*M* NaCl solutions.

Juda and coworkers (7) found for a phenolsulfonic resin membrane (Nepton CR-51) that the ideal membrane equation (X) was satisfied within seven per cent up to sodium chloride concentrations of the order of 0.1*M*. As the solution concentration increases, however, the discrepancies become appreciable. This may be compared to the potentials measured by Sollner (51) across permselective collodion membranes. He computed a cation transference number, T_+, of 0.971 from the membrane potential measured between potassium chloride solutions of 0.2*M* and 0.1*M* and, for 0.4 and 0.2 solutions, T_+ was found to be 0.935. The specific resistance of the permselective collodion membranes is between ten and one hundred times higher than of the homogeneous Nepton CR-51 material.

In the evaluation of all these measurements, water transport across the membranes was neglected.

There also seems to exist a lower limit to the applicability of equation (X). Discrepancies were observed at solution concentrations lower than of the order of $10^{-4}M$.

TABLE V. *Potentials obtained at 22°C using bonded Amberlite IR-100 and methyl methacrylate plastic and hydrochloric acid solutions of* pH *approximately 0.0 and 1.1** (62).

Electrode No.	Comp. of membrane by weight %	Thickness of membrane mm	Mean emf obs mv	emf obs with glass electrode† mv
H1	20 H Amberlite 80 Plastic	2.0	65.3 ± 0.1	64.3
H2	20 H Amberlite 80 Plastic	2.0	65.4	64.3
H3	20 H Amberlite 80 Plastic	2.0	63.9	64.3
Na4	25 Na Amberlite 75 Plastic	3.5	65.4	64.3
Na5	25 Na Amberlite 75 Plastic	2.5	65.4	64.3
Na6	25 Na Amberlite 75 Plastic	3.0	64.7	64.3

* Reproduced by permission of the *Journal of Physical Chemistry*.

† Difference between potentials measured first in one hydrochloric acid solution and then in the other with a Beckman glass electrode and a saturated calomel reference electrode.

The use of cation-exchange membrane electrodes for the measurement of cationic activities is seriously limited by the interference of other cations. If more than one type of cation is present in the solution on one side of the membrane, the relationship between potential and activity of any particular ion is complex. In some cases, membrane electrodes may still prove useful, if properly calibrated, but, in general, their degree of specificity is low if compared to the specificity of the glass electrode for hydrogen ions.

Analogous results were obtained for anion-exchange membranes (8, 9, 60).

By measuring the membrane potentials as a function of the activities of the solutions on the two sides of the membrane, the mean activity coefficient $(\gamma_\pm)'$ of the mobile ions in the resin can be determined from modified equation (XII), if the capacity of the resin is known. Bonhoeffer and coworkers (9, 52, 60) estimated the activity coefficients of different 1-1 electrolytes in different resins by this method. Using some simplifying assumptions, they compared the exchange-equilibrium constants predicted from these potential measurements to the values found by experiment. For a cation-exchanger with strongly acid groups (Wofatit 21), the agreement was within the limit of error of the measurements. (The limit of error in the determination of $(\gamma_\pm)'$ was estimated at 15 per cent.) For a polyfunctional cation-exchange resin with weakly acid groups (Wofatit 24) and a polyfunctional anion-exchange resin (Wofatit 35), equation (XII) cannot be expected to hold and, while the activity coefficients estimated from the membrane potentials predicted qualitatively which ions are preferred by the exchange-resin under given conditions, quantitative agreement with the exchange adsorption data was no longer found. It was also established from the measurements that for KCl, NaCl, and LiCl the mobility ratio m_+/m_- in the exchanger is about the same as in aqueous solutions, although the absolute values of the mobilities are much lower.

A somewhat different method was used by Juda and collaborators (7, 8) to evaluate potential measurements across a cation-exchange membrane (Nepton CR-51) and an anion-exchange membrane (Nepton ARX-44), and to correlate them to conductivity data and to the amount of electrolyte in the membrane determined by direct analysis. The conclusion was reached that the exchange groups in Nepton CR-51 are strongly acid and in Nepton ARX-44 they are weakly basic.

Water Transport Across Ion-Exchange Membranes

In the previous considerations of this article, the water transport associated with the ion transport through ion-exchange materials has been neglected. Water can be transported through the ion-exchanger as hydration water of the mobile ions, which represents water strongly bound to the ions, and as water carried along with the ions and not tightly bound to them, viz., electroosmotic transfer of water. Any exact electrochemical theory of ion-exchange resins must take this phenomenon into account. A discussion of this effect, based on experiments with collodion membranes, has been presented by Schmid (40, 63–65).

When electric current passes through a solution of an electrolyte, a viscous drag is exerted on the solvent by both cations and anions. Since the force exerted by the migrating ions is equal but in opposite directions, no net transfer of solvent occurs except for the effect of the water of hydration. In an ion-exchange resin, however, one type of ions is immobile. The force exerted on the solvent by the mobile ions would not be counter-balanced if the solvent were to stay at rest and, therefore, the solvent moves in the same direction as the mobile ions and at a rate determined by the friction between itself and the ions and the resin matrix, respectively.

While the theory of electroosmosis in ion-exchange membranes has been discussed in considerable detail (64), and direct measurements made of the electroosmotic transfer of water across membranes of collodion (65) and other membrane materials, very few measurements have been reported for synthetic ion-exchange resins. According to Rosenberg (66) the water transport between very dilute solutions of sodium chloride across a Nepton CR-51 membrane in the sodium form is about 300 ml/equivalent of sodium ions. In other words, each sodium ion transports about seventeen water molecules.

This effect must be taken into account in the interpretation of ion-exchange membrane potentials and of resin conductivity data. If current is drawn from two silver-silver chloride

Editorial

Our Antiquated Anti-Trust Law

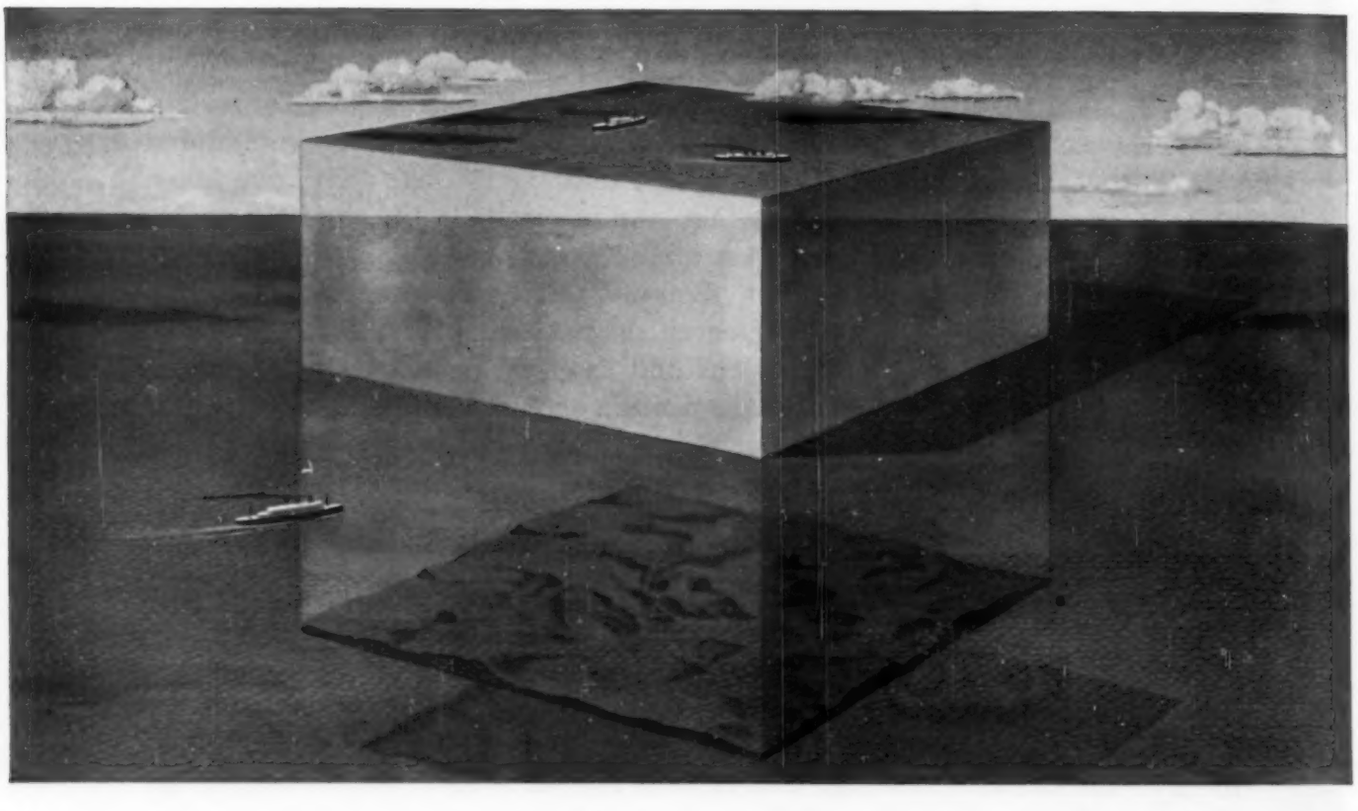
IN addressing a recent convention of the Industrial Research Institute on "Legal Problems in Cooperative Research," John T. Cahill pointed out that, while science has made stupendous contributions to modern life in the past sixty years, the law has gone backward and has not yet entered into 20th century affairs. He cited the fact that the changes that have taken place in transportation, communication, and in our daily life since the enactment of the Sherman Anti-Trust Act in 1890 are far greater than those that occurred during the preceding two thousand years. These changes are due chiefly to large scale organized research deliberately planned and financed.

Without questioning the significant and essential contributions of fundamental research, the great practical scientific achievements that characterize present-day life are the fruits of the efforts of large industrial enterprises. Our leadership in the western world, the character of our civilization, and our very survival depends upon maintenance of superiority in scientific research. This requires individual and cooperative effort on an increasingly larger scale. Yet the law views cooperative research with distrust and hostility, and suspects conspiracy in any partnership effort of large corporations to solve large problems. There is a fear of bigness that leads to ridiculous action. For example, the Government's Department of Justice has brought suit against a big company to separate it from its research unit, while, at the same time, another department of the Government that understands the value and effectiveness of the research, engineering, and manufacturing capacity of an integrated organization has employed this same company to undertake a tremendous project in the national interest.

Perhaps the worst feature of trying to apply an 1890 law to modern affairs is the general doubt as to the application of the law to specific situations and problems. A famous jurist has said that the law is what the judges say it is. In any case, it is clear that the anti-trust laws will not be modernized or replaced by sensible provisions until the general public appreciates the nature and requirements of present-day industrial research and the restrictive influence imposed by antiquated laws. —RMB

THE SEA IS AN INEXHAUSTIBLE SOURCE OF AN IMPORTANT METAL

Each cubic mile of sea water contains six million tons of MAGNESIUM, the lightweight metal of so many uses



Today, when this nation is confronted with a crisis in our supply of many raw materials, it is of immense significance that the sea around us contains an almost unlimited supply of Magnesium. For Magnesium is light, strong, practical and versatile—the answer to many manufacturers' needs. Also, Magnesium is highly important in many electrochemical processes including cathodic protection.

Dow began research on the extraction of Magnesium from brine over forty years ago. In 1941, at Dow's Freeport, Texas Plant, *the first commercial extraction from sea water was begun.* Dow pioneered in the production and development of Magnesium and its alloys and remains the leading producer and fabricator today.

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DOW

Reminiscences on the Wrightsville Beach Meeting

If Dolly* hadn't gone off to sea, it might have been quite different. At one time she showed signs of being on hand for the Wrightsville Beach Meeting, but fortunately was diverted elsewhere by forces that were stronger than the attractions of our meeting—great as these were. But she did cause the local committee considerable concern, since the elevation of Wrightsville Beach is not much over five feet at high tide, and a combination of hurricane tides and waves might have necessitated a general evacuation as the first activity after registration.

Instead, the immediate result was a general clearing of the atmosphere in that area, and a week of ideal weather. With due respect to the benefits derived from participation in the technical sessions, those who attended this meeting are likely to remember most how pleasant it was. This is particularly true of the ladies, who were well represented in the ratio of about 1 to 3. This may constitute a record of some kind.

The ladies seemed to enjoy their activities which depended principally on the natural resources of the locality and particularly the ocean beach. The temperature of the water was about right, 25°C (77°F) (especially appropriate for electrochemical undertakings of a fundamental nature). During the day the air temperature was a few degrees warmer and during the night a few degrees cooler—thus appealing both to those who like it one way and those who like it the other. The latter group appeared to be even more exuberant than the former, or maybe it only seemed so in view of the relative absence of other sounds after midnight. The nocturnal class also were treated to a fine display of phosphorescence in the breaking waves or created by the turbulent but otherwise fairly well controlled motion of their bodies through the water.

The wind kicked up a bit of a fuss on Thursday and some of our members encountered a little difficulty in a valiant and successful effort in rescuing a little girl who got caught in a sort of undertow near a jetty. Two spent a day in the hospital and a third was confined to his quarters in the hotel. Two others recovered more quickly from their ordeal. A colored boy who worked at the hotel as a bell hop was especially helpful in rendering assistance in the rescue operations. His efforts and bravery were recognized in the form of a cash reward provided by the members of the Sea Horse Institute and presented to him at their meeting on Friday morning.

Attendance was much greater than many anticipated. Before the week ended, about 500 assorted electrochemists, Sea Horses, and Marine Borers showed up. This was a mixed blessing. It complicated the housing situation by making it impossible for the hotel people to give everyone exactly the type of accommodations he wanted and had been promised. This naturally bothered a lot of people at the

* Hurricane number 4 of the 1953 late summer series.

Scenes from the Wrightsville Beach Meeting, September 13 to 16, 1953

outset, but apparently the otherwise salubrious atmosphere and the opportunities for pleasant associations in congenial company had a soothing effect, so that one got the impression that everyone was enjoying himself before the meeting ended.

The above estimated attendance provided an income from registration fees sufficient to encourage the committee to give the ladies a little more than had been originally planned—this included a complimentary luncheon and a two-hour boat ride on the Inland Waterway. What seemed to be a particularly noteworthy feature of their guided tour was the police escort for the 20-car caravan on the 25-mile trip to Wilmington and back. What with sirens sounding off, disregarding red lights and stop street signs, and parking in restricted areas, the ladies must have felt that their importance was being recognized in no uncertain way. Their sight seeing tour was made especially pleasant by having a lady from the Wilmington Garden Club in each car to serve as a guide and to draw attention to points of particular interest.

The technical meetings were very well attended. Two of the meeting rooms were average; the third, the local theater, was unusually good. The seats were comfortable, it was air conditioned, the acoustics were excellent, and the facilities for projecting slides were fine. Having in mind the several deficiencies of any meeting rooms in hotels, one wonders why an effort should not be made to secure the use of theaters in other places for technical meetings, especially during the day when it might not cost too much to persuade a theater manager to give up the regular program for a couple of afternoon technical sessions.

The organized social functions did not attract as great a proportion of the attendance as had been anticipated, except for the barbecue dinner about which more will be said later. Evidently there was a good deal of competition from other gatherings of a more casual, but not to say disorganized, nature. The barbecue dinner ran into difficulties; probably the most important was that many of the members discovered they didn't like barbecue. But this discovery came too late in many instances, further complicating the situation. The quantity of food provided was based (it was thought reasonably) on the number of barbecue dinner tickets that were purchased. This amounted to about 280. But, much to the surprise of the caterer and the committee, some 350 appeared to be served. And strangely enough the extra 70 of our members—or maybe they were casual beachcombers—evidently were first in line and consumed so much of the chicken that there wasn't any for those who had lingered too long at one or other of the gatherings that preceded this affair. At least, the committee assumed that those who complained about this meal were those who had paid for it rather than those who had not. The other meals were quite satisfactory. Those who attended the reception and banquet at which Dr. Furman was given the Palladium Medal got quite a bit for their money in comparison with big city prices. They also were treated to as well phrased a citation by Dr. R. M. Burns and acceptance by Dr. Furman as they are likely to hear on any similar occasion.

Not many of the members seemed inclined to dance after the banquet. This was a disappointment to the orchestra leader who felt somehow that his efforts were not being appreciated. But what dancing there was made up in enthusiasm for what it lacked in extent. This was especially true of the display by some of the local talent, including members of the committee.

Progress in electronics was demonstrated in a way that might have pleased this Division of our Society. It so happened that a couple of our members became confused and boarded a bus heading for the train when they really wanted to go to the airport. Their error was discovered right after they left by Bill Dawson, who was in charge of transportation details. Bill enlisted the help of the taxi people with their two-way radio communication. By this means, they soon got a fix on the position of the bus, had it intercepted by one of the cabs, and took the airplane passengers off, getting them to the airport in time.

Although there were some expressions to the effect that future meetings might be held at Wrightsville Beach again, it doesn't seem likely that this will occur very soon. The local committee worked hard, but seemed to enjoy the activity and indicated they would welcome a return visit by the society. *F. L. LaQue*

Ten-Year Index Available

The Ten-Year Index, recently authorized by the Board of Directors, for Volumes 81 to 98, will be mailed late in December to those who have ordered it.

Those who wish to take advantage of the prepublication price of $10.00, and who have not previously ordered the Ten-Year Index, must place their order by January 1, 1954. Price of index ordered after January 1, 1954 will be $15.00. These prices and time limit for ordering at the prepublication price have been established by action of the Board of Directors.

DIVISION NEWS

Battery Division

The annual business meeting of the Battery Division was held following the Divisional luncheon in the dining room of the Ocean Terrace Hotel on September 14, during the fall meeting of the Society at Wrightsville Beach.

The meeting was called to order by the Chairman, E. Willihnganz. This was the mid-term annual business meeting at which no elections are held. The Secretary reported that membership in the Division was 299 at that time.

In order to make possible the publication of extended abstracts prior to future symposia, the necessity for the dues permitted by the Bylaws (Article III, Section 2) was discussed. It was voted to levy and collect the dues on a two-year basis (one dollar per year).

John Mrgudich was appointed chairman of a committee to handle the publication of a book on primary batteries.

The possibility of an award in the field of battery chemistry was suggested as a subject for consideration and discussion at the next meeting.

E. J. Ritchie, *Secretary-Treasurer*

Primary Battery Round-Table

A round-table discussion on the subject of "Low Temperature Properties of Primary Cells" was held on September 14 at the Wrightsville Beach Meeting by the Battery Division. The following program was arranged by Dr. J. J. Coleman of the Burgess Battery Company:

1. Opening address—The Requirements for Low Temperature Batteries. A. F. Daniels.

2. (*a*) Effect of Anodic Design upon the Low Temperature Characteristics of Dry Batteries.
   (*b*) Effect of the Characteristics of Separators on the Low Temperature Performance of Dry Batteries.
   (*c*) Effect of Depolarizer Composition on the Low Temperature Performance of Dry Batteries. A. F. Daniels.
3. Low Temperature Behavior of Mercury Cells. T. C. O'Nan.
4. Lithium Chloride Batteries. O. W. Storey.
5. Lithium Chloride Batteries. R. C. Evans.
6. High Zinc Chloride Dry Cell for Low Temperature Use. W. S. Herbert.
7. Low Temperature Behavior of Magnesium Batteries. R. C. Kirk.
8. National Bureau of Standards Low Temperature Batteries. E. Otto.
9. The Low Temperature Battery as a Proving Ground for Cell Components. M. R. Hatfield.

The above papers, which served as the basis for discussion of various phases of the subject, were presented by representatives of both battery manufacturers and government agencies. Their reports covered a considerable amount of technical effort, most of which has been expended in the past few years. In his capacity as chairman of this round table, Dr. Coleman deserves praise for a very interesting session.

Approximately 100 persons attended the round table, and about 75 of these were present at the Battery Division luncheon held at the Ocean Terrace Hotel. The primary battery round table program was too long to be completed in the morning so an afternoon session was arranged. The competition of the secondary battery round table, also in session in the afternoon, reduced the attendance at the primary meeting to about 70. Considering the location of Wrightsville Beach, this attendance marks an unusual interest in the subject of batteries.

N. C. Cahoon, *Vice-Chairman*

Corrosion Division

A business meeting of the Corrosion Division was convened by Chairman Fred Fink on Tuesday, September 15, immediately after the Division luncheon at the Hotel Kitty. Secretary-Treasurer H. A. Robinson reported a balance of $32.18 in the treasury, there having been no income or disbursements during the past year. Dr. Norman Hackerman, reporting for the Nominating Committee, presented the following slate of candidates in view of the resignation of H. A. Robinson:

Chairman—W. D. Robertson
Vice-Chairman—J. V. Petrocelli
Secretary-Treasurer—C. V. King

The above officers were unanimously elected and installed.

Following this, the incoming Chairman, Dr. Robertson, spoke briefly of his plans for the Boston Convention of the Corrosion Division, proposing that a symposium be held on the subject of stress corrosion. Inasmuch as this field continues to be quite active and the last symposium (ASTM-AIME) on the subject was held in 1944, Dr. Robertson felt that it would be both appropriate and fruitful to put a major amount of emphasis on papers treating of this phase of corrosion phenomena. He promised to bend his efforts to that end and asked for the cooperation of all members of the Corrosion Division in attaining this objective.

H. A. Robinson, *Secretary-Treasurer*

Electrodeposition Division

At its annual Division luncheon on Tuesday, September 15, during the Wrightsvil e Beach convention, the Electrodeposition Division held a short but lively meeting. M. L. Holt, Division Chairman, exhibited the page proofs of the revised edition of *Modern Electroplating*, and reported that publication was scheduled for November 1953.

The Executive Committee agreed to meet in the spring and to draw up recommendations as to how proceeds from the book shall be utilized. These recommendations are to be submitted to the membership at the fall business meeting.

In addition to subjects for future symposia, possible topics for a Round-Table Discussion or for an Educational Review Session were discussed.

S. Barnartt, *Secretary-Treasurer*

SECTION NEWS

Cleveland Section

Officers elected by the Cleveland Section for the 1953–54 season are as follows:

Chairman—N. C. Cahoon
Vice-Chairman—E. B. Yeager
Treasurer—W. H. Stoll
Secretary—M. E. Sibert

The first meeting of the season was held on Tuesday, October 13. C. L. Wilson, Professor of Chemistry at Ohio State University, spoke to the section on "Organic Reactions at Electrodes." Dr. Wilson is also Chairman of the Electro-Organic Division of The Electrochemical Society.

The probable mechanisms of certain anodic and cathodic organic reactions were discussed primarily from the standpoint of where a reaction takes place and what specific reagents are involved. Such reactions apparently proceed in different manners dependent upon overvoltage of the cathode employed.

Commercial applications of electro-organic reactions were discussed. An industrial future appears promising for this field.

M. E. Sibert, *Secretary*

New York Metropolitan Section

The first fall meeting of the New York Metropolitan Section was held on September 30. Present as a guest was Dr. R. K. Ram Prasad of the India Section, who spoke briefly of the activities of the Indian Section and of electrochemical industry in India.

The guest speaker for the evening was Dr. D. H. Baird of Sylvania Electric Products Inc., who spoke on the Ultra-Purification of Rare Metals with Special Reference to Germanium. He stated that we were discussing a new method of purification by which a purity of 1 part in 10^9 is obtainable in germanium in contrast to a purity of 1 part in 10^6 obtainable by other methods. In this method an ingot of germanium in a graphite boat is placed in a quartz tube which is filled with an inert atmosphere. A high frequency coil is moved along the tube, which moves a molten zone through the ingot. The impurities are concentrated in the molten metal and carried by the molten zone to the end of the bar. Dr. Baird pointed out that this method of purification was not peculiar to germanium but could be used with other metals as well.

The speaker outlined the method of preparation of pure germanium. The

first step is chemical. Germanium oxide is converted to the chloride and the chloride purified by distillation. The germanium is then precipitated as the hydroxide which is heated to convert it to oxide. The oxide is reduced to metal with hydrogen. The resulting bar is purified by zone melting. A series of induction coils is passed over the bar, or the bar is passed through one coil a number of times until the desired purity is obtained. After purification a very small amount of a desired impurity is added to give the metal the required conductivity. The conductivity of the metal is the best measure of its purity since the impurities are present in amounts too small for detection by ordinary chemical methods.

In discussing the theory of purification by zone melting, Dr. Baird stated that this method is a modification of purification by normal freezing. In a freezing melt, the concentrations of impurities in the solid and liquid phases are not equal. The relation is given by the equation: C (solid)/C (liquid) = K which states that the concentration of an impurity in the solid phase divided by its concentration in the liquid phase is equal to a constant. This constant is called the distribution coefficient and may be greater or less than one. The considerations which determine if this method is applicable to a system are whether or not the distribution factor is favorable and if the apparatus can be kept free of contamination. At the end of the talk Dr. Baird answered questions from the audience.

KENNETH B. MCCAIN,
Secretary-Treasurer

Niagara Falls Section

The October 14 meeting of the Niagara Falls Section at the Red Coach Inn at Niagara Falls, New York, had a record turnout of over sixty members and guests for the dinner and the talk afterward.

Dr. Bernard W. Gamson, Director of the Central Research and Development Division of the Great Lakes Carbon Corporation, was the speaker of the evening and presented a very interesting talk on "Industrial Carbon." Dr. Gamson reviewed the utilization of the various forms of carbon and graphite in industry and covered the technology of specific applications of these materials in key processes. The manufacture of carbon and graphite, including the processes, product distribution, and type of product obtained from solid,

BERNARD W. GAMSON

liquid, and gaseous carbonaceous materials, were described.

J. E. CURREY,
Secretary-Treasurer

PERSONALS

ISIDORE CROSS, formerly of Cedar Grove, N. J., is now associated with Harper-Leader, Inc., Waterbury, Conn. Mr. Cross has become part owner of this organization, which specializes in the precision plating of all precious metals. Bulk and still plating is also done and laboratory facilities are available.

WALDEMAR P. RUEMMLER, formerly plant manager of Eagle-Picher Company, East Chicago, Ind., has become affiliated with the National Lead Company in the capacity of production superintendent of their new cobalt plant in Fredericktown, Mo.

ROBERT B. WITTENBERG, formerly located in Easton, Pa., has accepted a position as general manager of the Chemical Division, General Tire and Rubber Company, Akron, Ohio.

CHARLES H. ORR, having finished his graduate work at Syracuse University, Syracuse, N. Y., has joined The Procter and Gamble Company, Cincinnati, Ohio, as a research chemist.

JAMES EMLEN has transferred to the Quaker Chemical Products Company, Conshohocken, Pa., as technical director. Mr. Emlen was formerly assistant director, Inorganic Research Dept., Pennsylvania Salt Manufacturing Company, Philadelphia, Pa.

WALTER L. BRYTCZUK, formerly refinery metallurgist, U. S. Metals Refining Company, Carteret, N. J., has been named director of research and development of the company.

J. W. CUTHBERTSON, A. E. DAVIES, AND R. M. ANGLES received the Westinghouse Brake and Signal Company Limited Prize for 1952–53 for their paper entitled "Complex Fluorides for the Deposition of Tin and Tin Alloys." The award was made at the Annual Dinner of the Institute of Metal Finishing, London, on October 13.

JAY C. HARRIS, previously assistant research director at Monsanto Chemical Company, St. Louis, Mo., was named director of the company's newly established research group, which will be located in Dayton, Ohio.

SAMUEL COTTRELL has been promoted to vice-president of Mathieson Agricultural Chemicals Division, Mathieson Chemical Corporation, with headquarters in Little Rock, Ark. Mr. Cottrell will continue as director of operations of the division's seven plants located in Arkansas, Arizona, Texas, North Carolina, and Pennsylvania, a post he has held for the past year.

M. S. THACKER, Indian Institute of Science, Bangalore, India, has been elected to the following: Advisory Committee, Arid Zone Research, UNESCO; Board of Scientific and Industrial Research, India; Board of Engineering Research, India; National Telecommunications Research and Development Advisory Committee, Ministry of Communications, Government of India.

N. B. SHIVARAMAN, assistant engineer, Tata Chemicals Ltd., Mithapur, India, has been promoted to industrial engineer.

B. K. RAM PRASAD has left India on a four-month tour of Europe, England, and the United States to study the latest developments in electrical and electrochemical-metallurgical industries and research.

B. NARAYAN DAS, formerly at the University of Annamalai, has joined the Department of Chemical Technology, University of Bombay, Bombay, India.

H. VENKATAKRISHMA UDUPA, ATIRA, Ahmedabad, has been appointed Senior Scientific Officer, Central Electrochemical Research Institute, Karaikudi, India.

K. K. CHERIAN has left for Canada for post-graduate studies in metallurgical engineering at McGill University, Montreal, Canada.

S. SOUNDARARAJAN has been appointed research assistant, Department of General Chemistry, Indian Institute of Science, Bangalore, India.

ROBERT A. WITHERSPOON

Robert A. Witherspoon, former chairman of the executive committee of Shawinigan Chemicals, Ltd., and a pioneer in the building of Quebec's electrochemical industry, died on October 25th at his home, 94 Thurlow Road, Hampstead. He would have been 77 on October 31st.

He was buried in Mount Royal Cemetery, after a funeral service in his home.

Born in Rochester, N. Y., Mr. Witherspoon graduated from the University of Rochester and began his career as a laboratory boy in a chemical plant. In 1900, he was appointed an electrochemical engineer with the United Barium Company in Niagara Falls, N. Y.

In 1904, he moved to Shawinigan Falls, Quebec, one of the first few hundred citizens after the village was formed, as superintendent of the Shawinigan Carbide Company, which later became the Canada Carbide Company and eventually the Carbide Division of Shawinigan Chemicals, Ltd.

He became vice-chairman and general manager in 1929, president in 1935, and chairman of the executive committee in 1940. He retired in 1942.

Mr. Witherspoon was an early member of The Electrochemical Society, having joined in 1902, the year of its founding, and was president during 1932–33. He also received many honors from various international chemical organizations for his meritorious work.

NEW MEMBERS

In October 1953, the following were elected to membership in The Electrochemical Society:

Active Members

ANDREW BENKO, III, Metals Protection Co., mailing add: 19 Manor Road, Wexford, Pa. (Electrodeposition and Theoretical Electrochemistry)

PAUL DOIGAN, General Electric Co., Bldg. 7-282, 100 Woodlawn Ave., Pittsfield, Mass. (Electric Insulation)

FREDERICK FAHNOE, Vitro Corporation of America, West Orange, N. J. (Electrodeposition)

ROBERT KUNIN, Rohm and Haas Co., 5000 Richmond St., Philadelphia, Pa. (Industrial Electrolytic)

ELMER S. MCKEE, Catalyst Research Corp., 6101 Falls Rd., Baltimore, Md. (Battery)

ORVILLE W. REEN, Allegheny Ludlum Steel Corp., Carmet Div., 1500 Jarvis Ave., Detroit, Mich. (Electrothermic)

RAFAEL G. RODRIGUEZ, Bowers, mailing add: Galeana #405, Norte, Monterrey, N.L., Mexico (Battery)

JEAN SHIFFERS, Lavino Chemical Co., mailing add: 805 24 St., N.E., Canton, Ohio (Battery, Electrodeposition, Industrial Electrolytic, and Theoretical Electrochemistry)

GEORGE SLOMIN, Rohr Aircraft Co., 114 E. 18 St., National City, Calif. (Electrodeposition, Electronics, Industrial Electrolytic, and Theoretical Electrochemistry)

HAROLD F. WINDSOR, General Electric Co., mailing add: 222 Garfield Ave., Syracuse, N. Y. (Electronics)

Reinstatement

ROY C. SUNDEEN, mailing add: 2089 Lewis Dr., Lakewood 7, Ohio

Associate Member

DOUGLAS V. KELLER, JR., National Lead Co., mailing add: 532 Memorial Parkway, Niagara Falls, N. Y. (Electrothermic)

Student Associate Member

ALVIN P. GINSBERG, New York University, mailing add: 43 Amboy St., Brooklyn, N. Y. (Theoretical Electrochemistry)

MEETINGS OF OTHER ORGANIZATIONS

CHEMICAL INSTITUTE OF CANADA, 6th Divisional Conference, Analytical Chemistry Division, Royal Hotel, Guelph, Ontario, February 18–19, 1954; 8th Divisional Conference, Protective Coatings Division, Montreal, February 25, 1954; 8th Divisional Conference, Protective Coatings Division, Toronto, Feburary 26, 1954.

NATIONAL ASSOCIATION OF CORROSION ENGINEERS, Tenth Annual Conference and Exhibition, Kansas City, March 15–19, 1954.

TENTH INTERNATIONAL PRINTING, MACHINERY AND ALLIED TRADES' EXHIBITION, The Grand and National Halls, Olympia, London, July 5–16, 1955.

Dr. Fink's Door Knobs "Retired" to Museum

A set of common door knobs, well worn from 29 years of constant use, was "retired" on October 28 to the Chandler Chemical Museum at Columbia University.

The knobs, ordinary only in appearance, were among the first objects ever chrome plated by a successful commercial process. Dr. Colin G. Fink, inventor of the process, had the knobs plated on April 3, 1924, and put on the door of his laboratory in Havemeyer Hall at Columbia. They served as a showpiece and as a means of testing the resistance of the new plating.

As time went by, the original purpose of the knobs became more and more obscure until their celebrated background was lost to but a few people.

Upon Dr. Fink's death on September 16, a search was made for mementos of his many inventions. The existence of the historic door knobs was brought to light through conversations with Dr. Fink's associates and former students, and plans were made to preserve them.

In a brief, informal ceremony on October 28, Vernon Burr, who actually plated the knobs as Dr. Fink's laboratory assistant, removed them from the door and turned them over to Dr. John M. Nelson, curator of the Chandler Chemical Museum at Columbia.

Address Wanted

The Society does not have the address of Eugene Ashby who won Honorable Mention in the 1953 Prize Essay Contest sponsored by the Corrosion Division. It would be appreciated if anyone knowing his address would send it to Society Headquarters.

Correction

R. B. SNYDER has been named Second Vice-President of the Chicago Technical Council. Formerly he was associated with the Rauland Corporation. Since September 1, he has been with the Chemical Department of the Allen B. Du Mont Laboratories, Clifton, N. J.

LETTER TO THE EDITOR

Anodic Stripping of Zinc Immersion Deposits on Aluminum

Dear Sir:

Keller and Zelley, in their paper "Conditioning Aluminum Alloys for Electroplating,"[1] recommend a double zinc immersion treatment as a conditioning treatment in the electroplating of aluminum alloys. The first zinc coating is removed by a dip in 1:1 nitric acid followed by formation of a second coating, which is then electroplated. Edwards and Swanson[2] have recently discovered that the use of the first two steps of this treatment, when using the Vogt process for electroplating aluminum, permits the omission of stoving, which otherwise is required to secure satisfactory adhesion of nickel deposits.

The use of an anodic etch in the zincate solution has been tried by Knapp[3] and Loucks,[4] and suggested by Wernick.[5] Knapp found that poor nickel adhesion was associated with this type of etch, and Loucks found it to be effective in some treatments.

We have been investigating a variation of this double zincate procedure, suggested by one of the writers (DPS). The nitric acid stripping may be replaced by anodic stripping at 10–15 amp/dm² for periods of 1–3 sec. The zinc coating is formed by immersion in a sodium zincate solution at 25°C, of the composition described by Keller and Zelley, anodically stripped in the same solution, and followed by reformation of a second coating. The technique is quick, simple, and eliminates rinsing and nitric acid stripping procedures. This variation has been found to be without effect on the quality of the zinc coating or of subsequent electrodeposits.

The weight of zinc coating, formed on Alcan 3S sheet by immersion for several periods following various conditioning treatments, is listed in Table I.

TABLE I. *Effect of conditioning treatment on zinc coating weight*

Conditioning treatment	Zinc coating weight (mg/cm²)		
	Immersion treatment time (min)		
	1	2	3
None	0.116	0.145	0.170
Nitric acid stripping	0.021	0.037	0.035
Anodic stripping	0.020	0.022	0.031

The zinc coating weights found with various alloys, following the same conditioning treatments, are shown in Table II.

TABLE II. *Zinc coating weights on various aluminum alloys*
(Immersion time: 1 min.)

Alcan alloy	Zinc coating weight (mg/cm²)		
	No conditioning treatment	Nitric acid stripping	Anodic stripping
2S	0.314	0.020	0.020
3S	0.110	0.020	0.020
24S	0.047	0.042	0.057
57S	0.126	0.039	0.038
160	0.210	0.087	0.103

The effect of the following variables on the weight of the final zinc coating was found to be:

1. Initial immersion time before stripping: lightest coatings were produced by periods of 0.25 to 1 min. Longer periods may form heavier coatings.

2. Stripping current: 10–15 amp/dm² are adequate for quickly stripping the deposit. Lower current densities require longer periods, while higher current densities give heavier final coatings.

3. Stripping time: 1–3 sec were required under the conditions listed. Too long a period may anodize the aluminum, and produce a heavier final deposit.

4. Number of coating and stripping cycles: increase in the cycles from one to five raises the coating weight.

D. P. Seraphim
R. C. Spooner

Aluminium Laboratories Limited
Kingston, Ontario, Canada

[1] F. Keller and W. B. Zelley, *J. Electrochem. Soc.*, **97**, 143 (1951).

[2] J. Edwards and C. J. Swanson, *Trans. Inst. Met. Finishing*, **29**, Advance Copy No. 5 (1953).

[3] B. B. Knapp, *Metal Finishing*, **47**, No. 12, 42 (1949).

[4] J. Loucks, Aluminum Company of Canada, Ltd., private communication to the author.

[5] S. Wernick, *J. Electrodepositors' Tech. Soc.*, **27**, 257 (1950–51).

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RECENT PATENTS

Selected for electrochemists by Fred. W. Dodson, Chairman of the Patent Committee, from the Official Gazette.

August 4, 1953

Moore, W. E., 2,647,936, Electrode Clamp

Taylor, W. H., 2,647,938, Combined Electrolytic Barrier and Electrolyte

August 11, 1953

Kennedy, A. M., 2,648,595, Cyclic Process for Treating Aluminous Ores

Buser, J. S., Ded. by Morgan, D. E., administratrix, 2,648,625, Method of Electrocoating Strip

Buser, J. S., Ded. by Morgan, D. E., administratrix, 2,648,626, Method of Electrolytic Coating

Donnelly, H. G., 2,648,627, Bright Nickel Plating Composition and Process

Brown, H., 2,648,628, Electroplating of Nickel

Dvonch, W., and Mehltretter, C. L., 2,648,629, Electrolytic Preparation of Perio-date Oxypolysaccharides

Basilewsky, A., 2,648,630, Mercury Cathode Electrolysis Apparatus

Carlisle, J. V., 2,648,631, Fused Salt Electrolysis Cell

Williams, A. O., and McBurney, W. G., 2,648,714, Hood for Electric Furnace

Lillienberg, A. W., 2,648,715, Furnace for Molten Metal

Lindner, R. L., and Hayes, T. K., 2,648,716, Induction Furnace

Ross, S. D., and Schroeder, W. W., 2,648,717, Electrolytic Membrane

Sundeen, R. C., 2,648,718, Anode for Primary Galvanic Cell

August 18, 1953

Hippel, A. v, 2,649,409, Electrodeposition of Selenium

Bloom, M. C., and Levy, J. P., 2,649,410, Electrodeposition of Selenium

Shaw, H., Thompson, A., and Toler, T. I. J., 2,649,411, Mercury Cathode Electrolytic Cell

Phillips, M. W., 2,649,487, Immersion Heater for Bushing for Fiber Glass Manufacture

Turkington, R. D., 2,649,489, Thermocouple

Greenamyer, G. P., 2,649,490, Pilot Burner with Built-In Thermocouple

Lang, M., 2,649,491, Dry Cell

Linton, A., and Lewis, R. W., 2,649,492, Voltaic Cell

Temple, L. M., 2,649,493, Battery Connection

Martin, J. R., 2,649,494, Vent and Filling Device for Storage Batteries

Kennedy, H. A., 2,649,495, Battery Cap

Ment, De J., Application 772,859, Apparatus for Decontaminating Radioactive Ships

August 25, 1953

Johnson, F. A., 2,649,766, Electrolytes for Wet-Cell Storage Batteries

Goldstein, J., 2,650,169, Phosphorescent Coated Sheet Material

Teal, G. K., 2,650,191, Preparation of Two-Sided Mosaic

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Hogel, L. K. G., and Dreyfus, L., 2,650,255, Tilting Electrical Melting Furnace of Egg Shaped Cross Section

Lingane, J. J., 2,650,256, Automatic Electrometric Titration Apparatus

Jolley, E. L., 2,650,257, Lead-Acid Electric Storage Battery and Process of Producing Same

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MANUSCRIPTS AND ABSTRACTS FOR SPRING MEETING

Manuscripts are now being received for the Spring Meeting of the Society, to be held at the La Salle Hotel in Chicago, May 2, 3, 4, 5, and 6, 1954. Subjects to be covered at the technical sessions will be Electric Insulation, Electronics, Electro-Organic Chemistry, Industrial Electrolytics, and Theoretical Electrochemistry.

To be considered for this meeting, triplicate copies of manuscripts or abstracts (not to exceed 75 words in length) must be received at Society headquarters, 216 West 102nd Street, New York 25, N. Y., *not later than January 15, 1954.*

Pantchechnikoff, J. I., 2,650,258, Semiconductor Photosensitive Device

Webb, E. L., and Fox, R. C., 2,650,309, Scintillation Counter and Composite Phosphor Therefor

Bray, R., and Larkhorovitz, K., 2,650,311, Radiant Energy Detecting Method and Apparatus

Francis, V. J., and Nelson, E. H., 2,650,322, High-Pressure Metal Vapor Electric Discharge Lamp

September 1, 1953

Zelley, W. G., 2,650,886, Procedure and Bath for Plating on Aluminum

Holman, H. E., 2,650,900, Method of Producing Metal Mesh Screens

van der Horst, K. L., 2,650,901, Electroplating on Aluminum

Higgins, W. F., 2,650,902, Electrodeposition on Magnesium and Magnesium-Base Alloys

Garrison, J. W., and Lovett, A. B., 2,650,903, Protection of Molybdenum Against Oxidation

Davis, J. V., Chill, C. W., and Pianowski, L. J., 2,650,904, Oscillating Rail for Work-Immersion Machines

Leuchs, F., and Zollner, H., 2,650,943, Electrode of Carbon

Ipsen, H. N., 2,650,944, Electric Heating Apparatus

Herbert, W. S., 2,650,945, Primary Dry Cell

Winckler, G. A. F., Rose, H. W., and Reinhardt, O. K., 2,650,946, Battery

Dunham, R. S., 2,650,947, Primary Battery

Dorst, S. O., 2,650,975, Electrically Insulated Conductor and Production Thereof

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Foley, R. T., and Omley, H. A., 2,651,144, Glass-To-Metal Seal

Loewen, R. P., and Starr, J. H., 2,651,569, Method for the Production of Alloys

Longini, R. L., and Hushley, W. J., 2,651,584, X-Ray Fluorescent Screen

Lytle, W. O., and Junge, A. E., 2,651,585, Production of Electroconductive Articles

Brenner, A., and Couch, D. E., 2,651,608, Electrodeposition of Aluminum From Nonaqueous Solutions

Chester, A. E., 2,651,609, Method of Electroplating Copper

Chester, A. E., 2,651,610, Method of Electroplating Zinc

Carosella, M. C., and Mettler, J. D., 2,651,611, Electrowinning of Chromium

Haller, J. F., 2,651,612, Amperometric Analyzer

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Southern, R. L., 2,651,668, Crucible Interchanging Mechanism for Arc Melting Furnaces

Neumann, G., 2,651,669, Hermetically Sealed Storage Battery

Linder, E. G., 2,651,730, Method of and Apparatus for Utilizing Radioactive Materials for Generating Electrical Energy

Marrow, S. H., 2,651,745, Dry Rectifier Assembly

Nelson, M. O., 2,651,765, Hand Locking Battery Cable Clamp

September 15, 1953

McFerran, F. A., 2,652,358, Water Heater Fittings

Schneider, M. S., 2,652,359, Supporting Means Used in Connection With Electroplating Racks

Simmons, O. W., 2,652,440, Electric Arc Melting Furnace

Gynt, S. E., and Lundqvist, R., 2,652,441, Electric Melting Furnace

Scott, R. M., 2,652,442, Thermocouple

Klein, C. J., 2,652,461, Conductor Roll for Apparatus for Electrolytically Treating Strip

Pack, H. G., 2,652,503, Thermoelectric Generator

NEW PRODUCTS

"Slice-Away" Battery Assemblies. Two novel types of RCA alkaline battery assemblies which can be sliced, like a package of candy mints, into numerous combinations of cells to provide different voltage requirements have been announced, intended specifically for equipment designers and experimenters exploring application possibilities of transistors. Both battery assemblies (VS087 and VS088) are 21-volt special-purpose types. The RCA VS087 is designed for current drains up to 2 ma; the RCA VS088, which has larger cells and greater capacity, is designed for current drains up to 10 ma. RCA Victor Division, Radio Corporation of America. N-30

Colloidal Graphite Dispersion in Glycol. A new colloidal graphite dispersion known as 'Glydag' B is available

a source of colloidal graphite in rub-r-lubricant formulations. Ideal for use automobiles, motor-scooters, ma-rials-handling vehicles, and washing achines. Acheson Colloids Co. N-31

FLASK HEATERS. A new line of electric sk heaters for laboratories has been nounced, known as Forma-Heaters. ock sizes available for flask capacities om 500 to 5000 ml; sizes for other pacities available on special order. All zes come with or without thermo-gulators for temperature control. The aters are designed for repeated use er long periods of time; they have ilt-in clamps for ease of setup, and tional swing-away clamps for ease of ading and unloading while on frame pports. Burrell Corp. N-32

FREQUENCY METERS. A new line of equency meters for use in laboratory d field service is now being produced. he meters are supplied complete with icroammeter, sensitivity control, and alibration charts, and are housed in a ardwood carrying case with removable d. Accuracy is better than 0.05% from 0°-120°F; sensitivity provides usable indication with 1 milliwatt input; adjustable to accommodate higher levels. Frequency Standards. N-33

EXPLOSION-PROOF TROUBLE LAMP. A lightweight, explosion-proof trouble lamp, designed to assist maintenance work at hazardous locations where explosive gases or vapors are in the air has just been introduced. Especially practical for inspecting the interior areas of oil and gasoline drums or process vessels and tanks, as well as for illuminating inaccessible gauges. Crouse-Hinds Co. N-34

VERTICAL FLOW CABINET OVEN. A new standard-model vertical flow oven has been designed, combining features which reduce heat loss with corresponding greater efficiency and lower operating cost. Features are: no metal to metal contact, double gasketed doors with heat trap, 20% more insulation, and high-low selective heat intensity control. Grieve-Hendry Co. Inc. N-35

SOLUBLE SILICATES. Two new products have been added to the line of soluble silicates—anhydrous sodium metasilicate and sodium orthosilicate, known as Metso Anhydrous and Metso 200, respectively. Metso Anhydrous is a strongly alkaline detergent used for heavy-duty cleaning in the metal industries, in laundries as a soap builder, and for formulating specialized detergent compounds. Metso 200 is designed for cleaning operations that require extra strong alkaline activity, such as, cleaning of ferrous metals prior to electroplating and enameling, and soaker tank cleaning. Philadelphia Quartz Co. N-36

MOLECULAR VACUUM GAUGE. A new molecular vacuum gauge designed to measure pressures without external detectors has been announced. The instrument is available in two types, both covering the range of 0–20 millimeters of dry air. Identical except for scale marking, one is calibrated directly for dry air and the other has a linear scale for use where individual calibration for dry air or other gases is preferred. General Electric Co. N-37

SELF-LEVELING MOUNTINGS. Installing and leveling heavy machinery in minutes—without bolting or shims—is now possible with the new series LM3

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Please print your name and address plainly.

LITERATURE FROM INDUSTRY

"THE LABORATORY." 38-page publication (Vol. 23, No. 1) just issued has "the latest developments in laboratory instrumentation and technique." Feature article gives a comprehensive news report on the latest scientific attempts to conserve the world's art treasures. Also, other features and instrumentation section. Fisher Scientific Co. P-167

CARBON AND GRAPHITE PRODUCTS. Standard and special carbon and graphite components and materials for chemical, electrical, and mechanical applications are described in the recently revised and enlarged, 44-page Carbon Specialties Catalogue 40A. Stackpole Carbon Co. P-168

HAND PYROMETER. A 4-page booklet on the General Electric Type FH-1 hand pyrometer has been announced, containing information on specifications and accessories, and the uses and applications for the portable instrument, which measures temperature of any surface, liquid, gas, or molten metal, from 0°–1500°F. General Electric Co. P-169

MINIATURE MULTITESTER. Recent data sheet gives information on a Miniature Multitester combination volt-ohm meter for testing resistances and a-c or d-c voltages. The tester is small in size, designed for electronic equipment servicemen to use in the field. It has four d-c voltage ranges reading to 300 volts, four a-c voltage ranges reading to 600 volts, and four resistance ranges reading to 2,000,000 ohms: all selected from the front with rotary switch. International Instruments, Inc. P-170

ALKYL BENZENE. Procedures for obtaining a variety of surface active end products from the sulfonation of alkyl benzene are contained in a technical bulletin just published. Batch type manufacturing procedures are outlined for producing active sulfonates ranging from 40% to as high as 88% active. As a further aid to the processor in this field, the bulletin outlines analytical procedures for the usual general property tests to determine color, water content, per cent of sodium sulfate, and per cent of active content. Monsanto Chemical Co. P-171

HIGH-PURITY CARBON. A new booklet on a special extra-high-purity carbon raw material, called Gasco Carbon, contains useful technical information of especial interest to manufacturers; engineers; purchasing agents who buy solid fuel or carbon for chemical, electrochemical, or electrometallurgical processes; manufacturers of calcium carbide, silicon carbide, silicon metal, ferroalloys, and barium products; and producers who want to raise the carbon content of steel. Portland Gas & Coke Co. P-172

CRYSTOLON REFRACTORIES. A new 32-page manual entitled "Norton Refractories for Heat and Power" contains detailed information on the characteristics and manufacture of Crystolon refractories; Crystolon products for air-cooled wall protection, solid wall protection, water tube protection, and brick laying and general repairs; suggestions on use of the refractories for many different types of boilers; specifications on Crystolon brick and blocks; helpful curves on the thermal conductivity and thermal expansion of various refractories; and engineering tables. Norton Co. P-173

PRECISION BARREL FINISHING. A 32-page illustrated handbook and catalogue on "Lorco" compounds for descaling, deburring, abrasive cut-down, non-abrasive cut-down, finishing, coloring, burnishing, metal cleaning, and rust inhibiting has just been issued. Described in detail are 20 standard "Lorco" compounds and 3 special purpose compounds, giving industrial purposes, characteristics, uses, speci advantages, and field data. Lo Chemical Corp. P-17

"ELPHCO" ELECTRONIC RELA Bulletin describes the new "ELPHC Electronic Relay, Model No. 3, for t mercury thermoregulator. Electr Physics Co. P-17

"SCIENTIFIC APPARATUS AN METHODS." 32-page booklet (No. 1 Fall 1953) just published describ "Technique of Amperometric Titr tion," and apparatus and supplie Includes latest catalogue revisions. E H. Sargent & Co. P-17

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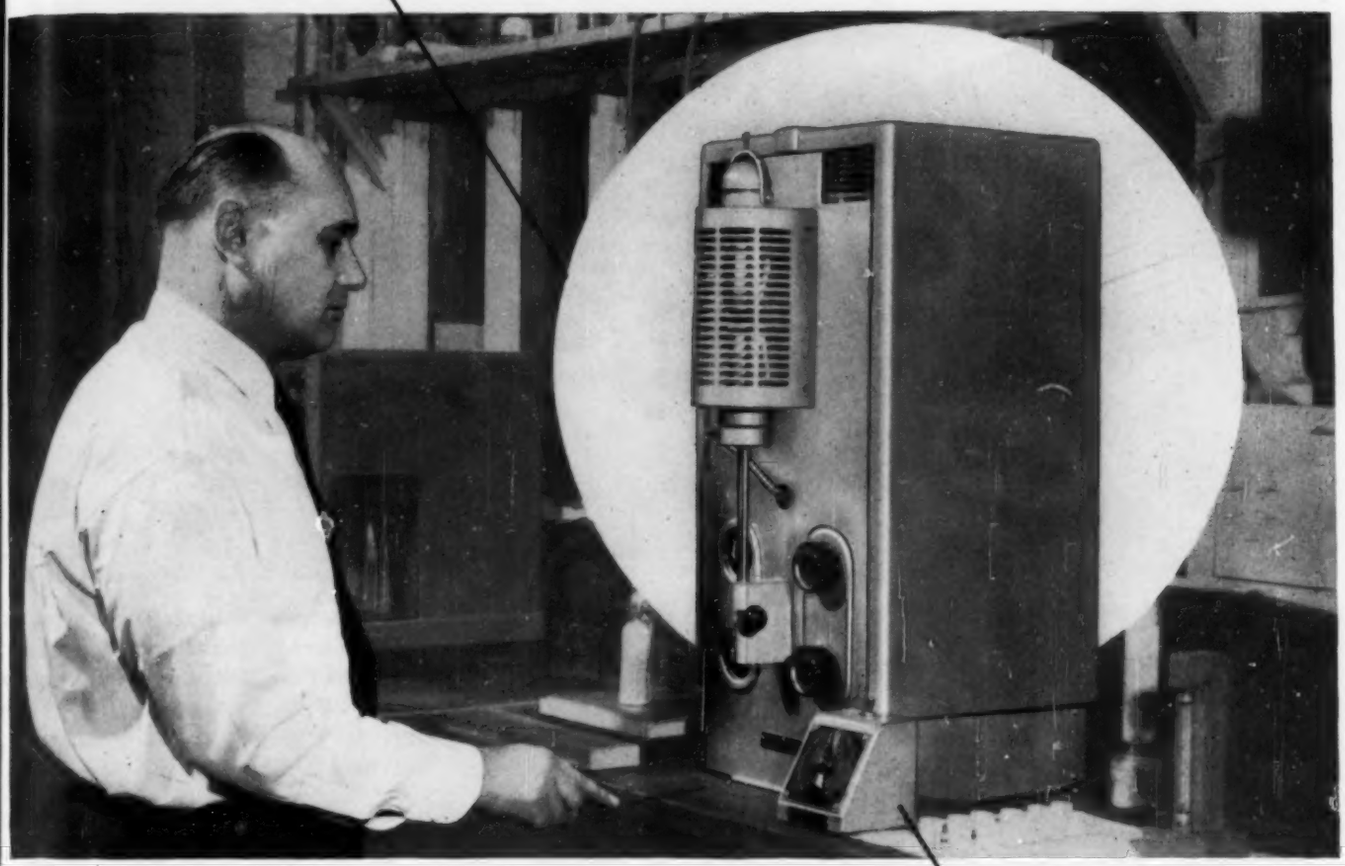

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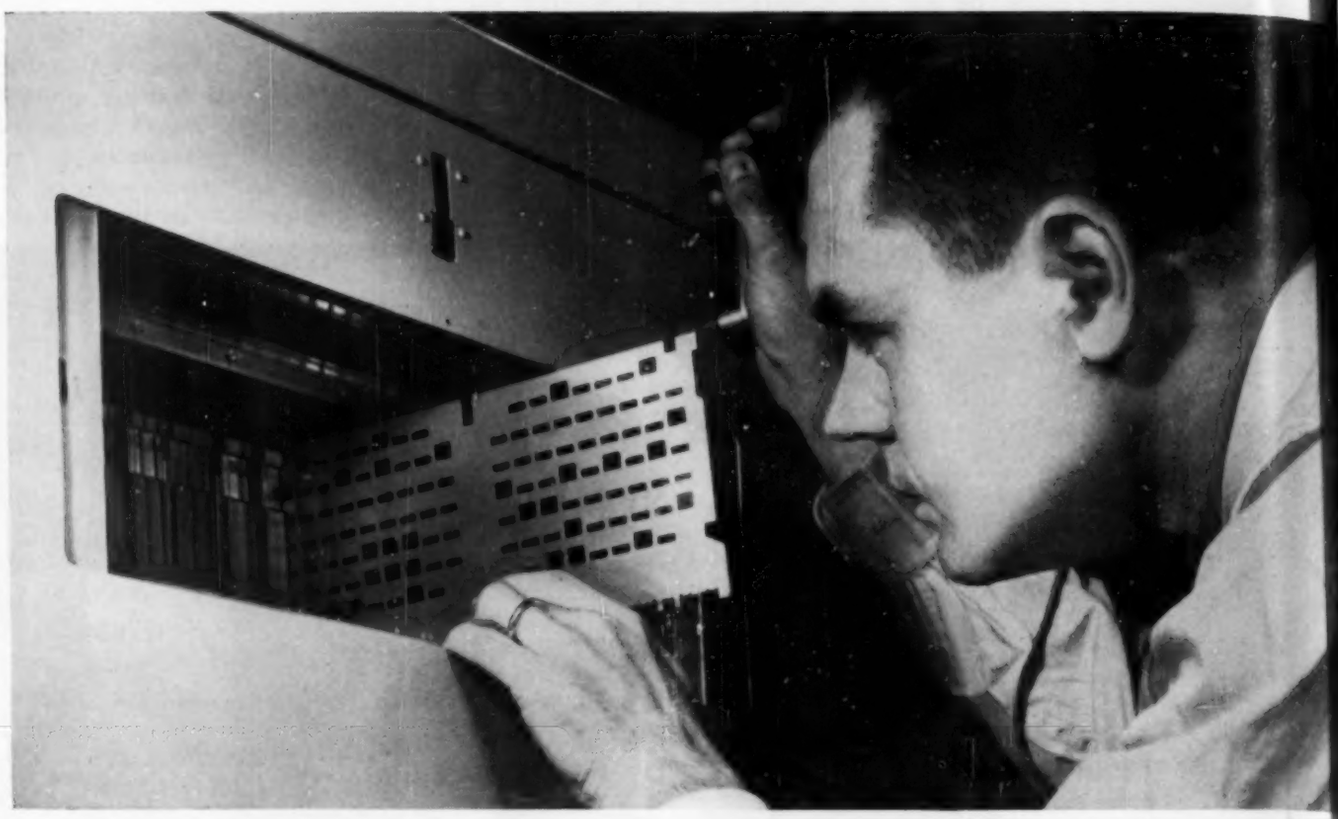

Checking perforated metal card in Bell's new "car file" which uses Phototransistors to help route Long Distance telephone calls along the best routes. If the first voice-way is in use, a "detour" is swiftly found. The equipment is known in telephony as a "card translator."

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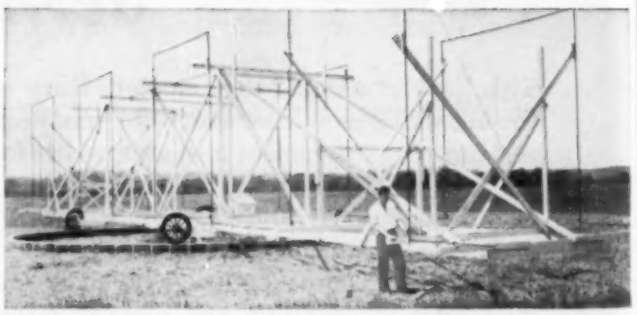

Directional radio antenna used by Karl G. Jansky, in the discovery of stellar radio signals at the Holmdel, New Jersey, branch of Bell Telephone Laboratories. In 1932 he detected waves of 14.6 meters coming from the direction of Sagittarius in the Milky Way.

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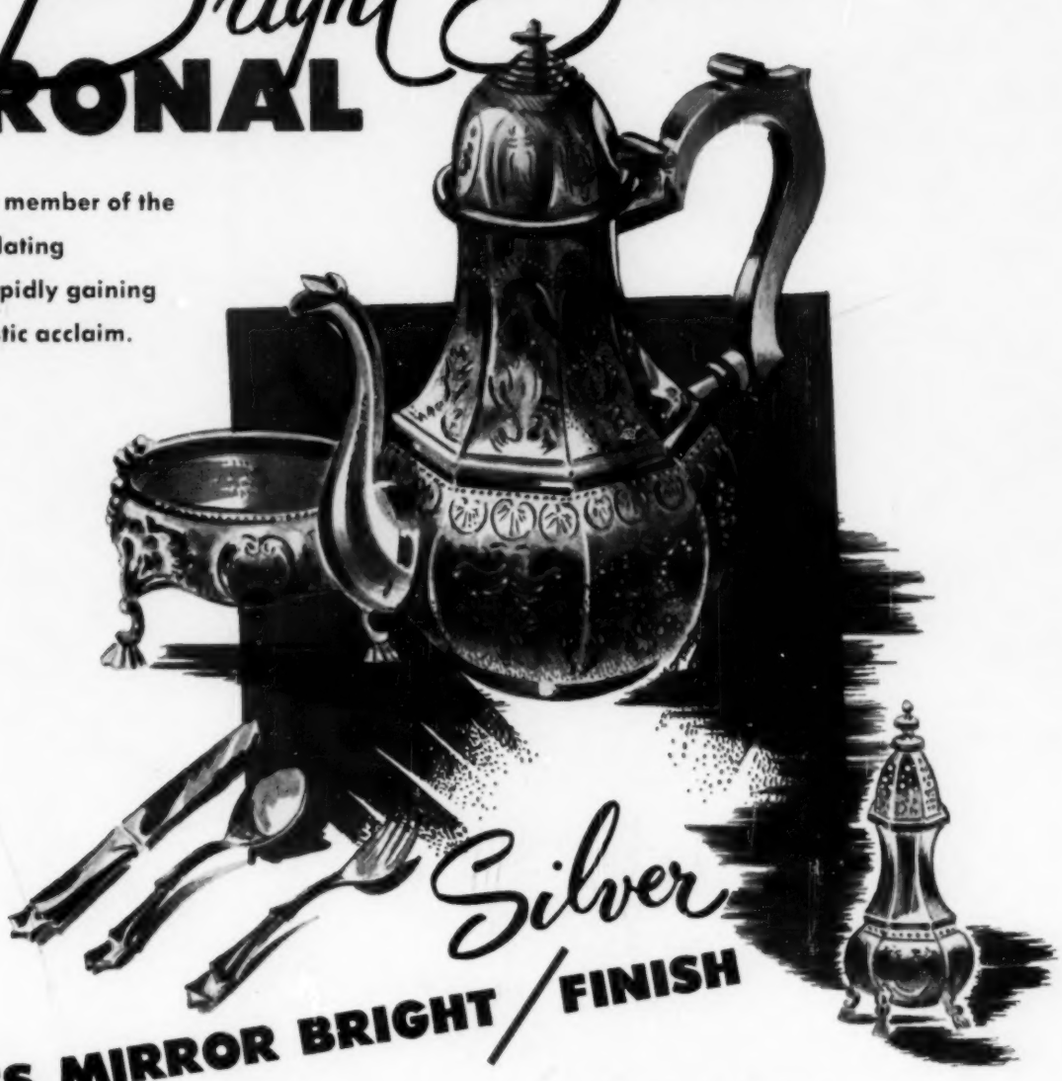

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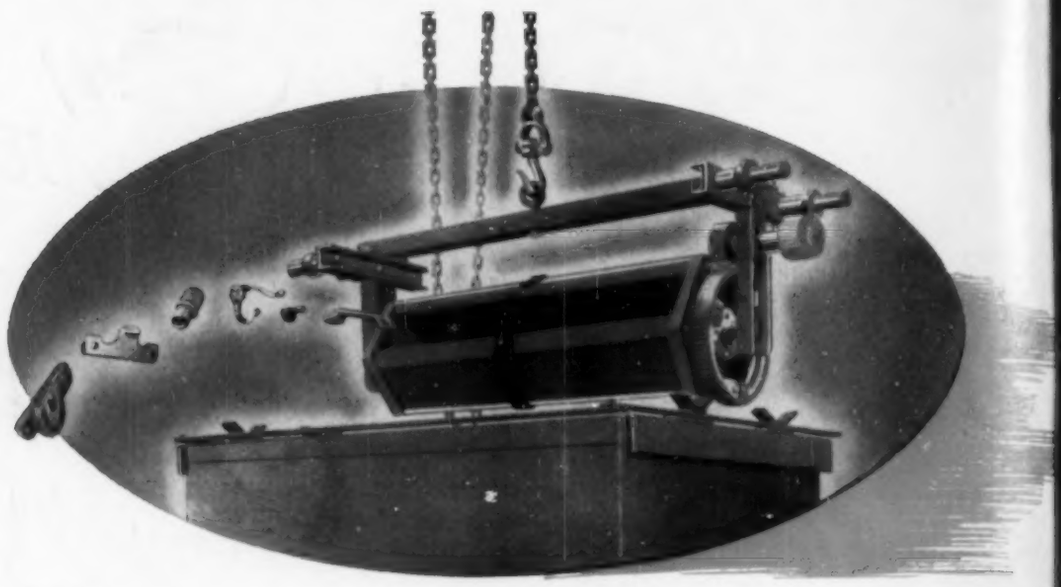

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Write for literature on Alumon and check list of literature on sixty Enthone products and processes for better metal finishing.

*TRADE-MARK REG. U. S. PAT. OFF. MANUFACTURED UNDER U. S. PATENT 2,142,564.

METAL FINISHING PROCESSES

ENTHONE
INCORPORATED
442 ELM STREET
NEW HAVEN, CONNECTICUT

ELECTROPLATING CHEMICALS